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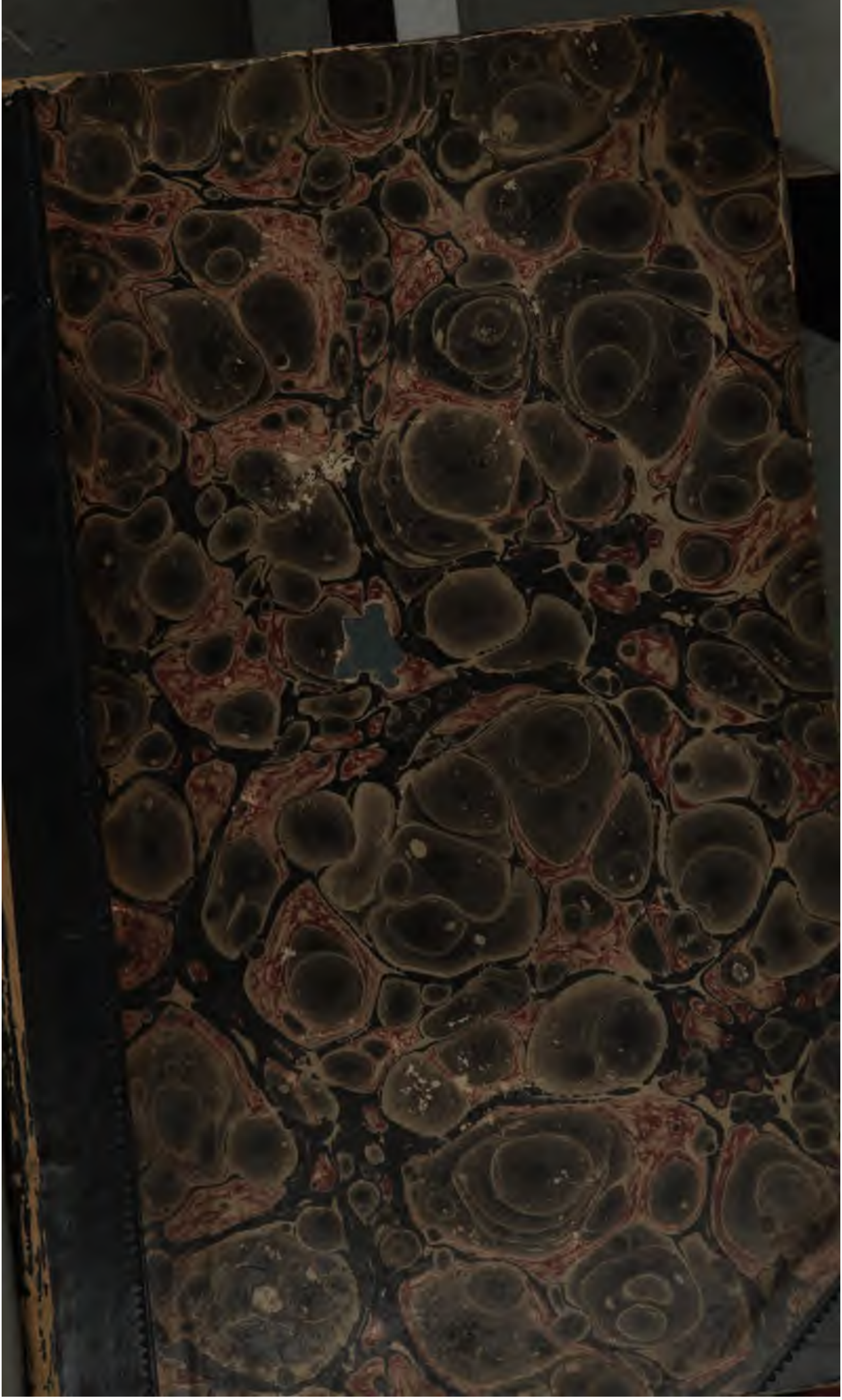

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OUTLINES

OF

HUMAN PHYSIOLOGY.

BY

HERBERT MAYO,

SURGEON, AND LECTURER ON ANATOMY.

LONDON:
PUBLISHED BY BURGESS AND HILL,
GREAT-WINDMILL-STREET.
1827.

PRINTED BY RICHARD TAYLOR,
SHOE LANE, LONDON.

ADVERTISEMENT.

THE following pages contain the heads of the Physiological Lectures delivered by the Author in the School of Great-Windmill-Street, together with a short account of the structure of the principal organs in the human body.

To be practically useful, a treatise on Physiology should present or recall to the mind of the reader a clear conception of the parts, the uses of which it describes: at the same time it must be short; and thus its scope is limited to a concise explanation of the more important functions of the body. A treatise fitting the magnitude of the subject would not suit the present thriving condition of Medical Science. So rapid is the progress of Physiology, that the first part of such a work would begin to be obsolete before the publication of the last; not to mention, that it would be too voluminous and expensive for students, and would be neglected by men advanced in the medical profession, for the scattered original essays from which it must have been compiled.

Physiology can only be adequately taught in Anatomical Theatres, when the Lectures of each year contain the discoveries of the preceding, and when the Lecturer turns from the actual demonstration of parts, to explain their uses. A treatise on Physiology, however excellent, can be of little service, except to those, who either are, or have been, engaged in such a course of study.

He who is acquainted with the healthy structure and functions of the body, is qualified to investigate disease. Anatomy is the first step in a medical education; Physiology the second; Pathology the third:—without the two former, Medicine and Surgery would be empirical arts, founded upon no principles, continually changing to suit the cleverest theory of the day, and calculated to be as destructive, as they are now beneficial to mankind.

19, George-Street, Hanover-Square,
January 1, 1827.

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ERRATA.

Page.	Line.	
22,	33,	*for* 1039 and 1059, *read* 1059 and 1089.
39,	7,	*for* the former, *read* belonging to either.
46,	19,	*for* attachment, *read* attachments.
64,	11,	*for* auricles, *read* auricle.
80,	23,	*for* descending, *read* ascending.
125,	6,	*for* longer, *read* larger.
127,	22,	*before* "the angle of the jaw," *insert* "In opening the mouth."
134,	24,	*for* palate bone, *read* hard palate.
170,	6,	*for* distant, *read* distinct.
181,	29,	*for* compression, *read* expression.
208,	8,	*for* reddish brown, *read* clear brown.
210,	16,	*for* that organ, *read* the nervous system.
238,	13,	*for* Meckel, *read* Gasser.
239,	*last line*,	*for* Meckel, *read* Gasser.
248,	31,	*for* cerebellum, *read* pons Varolii.
305,	20,	*for* devié, *read* droit.
336,	24,	*after* lungs, *insert* during respiration.

OUTLINES

OF

HUMAN PHYSIOLOGY.

CHAPTER I.

INTRODUCTORY OBSERVATIONS.

TO investigate the changes which Animals and Plants exhibit, to ascertain the means by which the phenomena of Life are produced and the laws which regulate their succession, is the province of Physiology. The study of this ample subject requires considerable anatomical proficiency, or a knowledge obtained by dissection of the structure of animals and plants, as well as an acquaintance with their external appearance and habits, or with their natural history, and elucidates the principles of the various arts by which man improves or modifies the nature and physical character of living beings of other species, or relieves the infirmities of his own.

The present work, which treats of a part only of physiology taken in an acceptation so general, contains a brief account of the human œconomy during health, intended to serve as an introduction to the study of disease. Independently, however, of a practical object, a speculative interest attaches to all researches of this nature, upon which I may be allowed to offer a few preliminary remarks.

He who examines the office of a single organ in an animal body, who investigates the laws of vision, or the means by which articulate speech is produced, experiences the same kind of surprise and delight, as upon witnessing some refined application of machinery. But while in the latter case his mind is occupied upon human invention only, and his surprise gradually gives place to a conviction that the design before him is yet imperfect, and admits of being simplified and improved,—in the former case his thoughts are raised to that Supreme Intelligence, which has fashioned elements that human hands cannot combine, for objects that human sagacity but partially comprehends; yet which, where understood, display in their attainment contrivance so perfect and infinite, as to lead irresistibly to a belief that nothing results fortuitously from properties inherent in matter, that Nature is the work of God.

The subsequent progress of a physiological student continually serves to illustrate the attributes of that Supreme Mind, whose marvellous design he is busied in unravelling. He reads in the careful provision for the perfectness and preservation of every species, and for the happiness of those which enjoy consciousness, a demonstration of an allwise benevolence; and he deduces from that remarkable analogy which pervades the innumerable families of living beings, stamping all in their various gradations and diversities with one common mark and impress, a confirmation,—if the expression be allowable,—of his belief in the unity of the Deity. From points yet more abstruse the veil seems partially withdrawn: the nature of life, the relation of the soul to the body, are more than indistinctly unfolded to his view. Principles even of moral conduct derive support in some instances from the inquiries of physiologists, which explain the physical connexion between the improvement or degeneracy of races or of individuals, and the observance or neglect of rules derived from higher sources. At every step is established some point of coincidence between the religion and morality of Nature and of Revelation.

Nevertheless it has been occasionally asserted, that the practical tendency of medical studies is to encourage irreligion, and that the theory of materialism is borne out by physiology.

The refutation of the first charge is easy by an appeal to facts. Harvey and Hales, Boerhaave, Haller, Baillie, are among the first names of eminent physicians or physiologists which occur to my recollection, and serve sufficiently to illustrate the frame of mind, as to religion, which has always attended genuine excellence in medical science.

The second imputation deserves to be examined the more attentively, because many are of opinion that the theory of materialism is essentially opposed to the doctrines of Christianity.

All who have reflected upon this subject concede, that mind and matter, the soul and the body, the phenomena of thought and a nervous system, are in the present state of our existence intimately associated. Every one is persuaded from general experience, that a powerful impression upon the mind affects the body, that the condition of the body influences that of the mind. But while many are content to suppose this union contingent, and that the soul may at another period exist unshackled by a corporeal frame, materialists attempt to prove that mind is the result of organization, that a portion of nervous substance, when existing under certain imperfectly ascertained conditions, necessarily produces thought.

If we abstract our minds from all preconceived ideas upon the subject, it must be admitted that there is nothing, which involves a contradiction in terms, or that is repugnant to common sense, in this supposition. In support of its justness, materialists borrow from physiology evidence of two kinds; consisting on the one hand of an analogical argument deduced from the relation between organs and their functions, on the other of direct proof of the close correspondence of the mental phenomena with the state of corporeal organs.

The analogical evidence brought forward in support of materialism contains a fallacy, the detection of which places in a very strong light the reasonableness of an opposite conclusion.

Physiologists have ascertained that different parts of the human body have different offices: that the formation of bile takes place in the liver, of saliva in other glands, that a power of shortening belongs to certain fibrous parts, that consciousness is connected with the nervous system. Now as the liver is admitted to be necessary for the separation of bile from the blood, as the power of shortening is the result of the structure of a muscle, it has been supposed to be an analogical inference that thought is the produce of the brain.

But the separation of one fluid from another, and the shortening of a fibre, are expressions which convey no meaning, if we attempt to abstract them from the notion of material organs or material substance. With the functions of the brain the case is different. Our conception of thought does not involve any attribute of matter; and we are struck with no speculative absurdity in supposing that our consciousness may survive, after every material element with which it has been connected shall have perished. Thus the analogy is destroyed between the dependence of thought upon the brain, and that of other functions upon other organs; and the argument founded upon it falls to the ground.

The second argument comprehends some curious details. If a portion of the brain be removed, the mind seems mutilated likewise. If a polype be cut in half, each portion appears to obtain independent consciousness. Facts of this description are indeed strikingly consistent with the theory of materialism, yet they are perfectly reconcileable with a different hypothesis. When we suppose mind and matter to be arbitrarily united, it is but reasonable to conclude that a very nice adaptation of the frame alone enables the mind to cooperate with matter, and we naturally anticipate, that what deranges the physical structure of the body will obscure the manifestations of consciousness. If it be difficult in this supposition to comprehend how matter can influence mind, it forms at least an equal difficulty in the theory of materialism to imagine how matter can produce mind. The apparent partitioning of consciousness upon the division of the lower animals, is analogous to the evolution of sentient existence by generation. We have to suppose that in the present scheme of the world there is a provision for adding a principle of consciousness to matter, when corporeally made a fit recipient for it. It might perhaps appear too great a concession to allow that the preceding facts tend to establish the theory of materialism, as much as the presumed fact of the renewal of the brain, while the conviction of our moral identity remains unchanged, tends to prove the reverse: yet these arguments on opposite sides may fairly be compared: they are both as unsound as they are plausible.

But the power, which we possess, of conceiving the separate existence of mind and of matter, constitutes each a substance logically distinct: and it forms no contemptible argument in favour of their essential independence, that although experience may be said in one sense to oppose it, our reason, in spite of experience, suggests and compels the belief that their present union is possibly contingent. For evidence to prove this supposition correct, we necessarily look elsewhere; my object is accomplished, if I have succeeded in showing that physiology does not lead to materialism.

It remains to confess that physiological attainments are not made without a sacrifice. The practice of dissection is repulsive to the imagination and to the senses, and the best sentiments of humanity revolt against the performance of experiments upon living animals: yet without the former no one would understand the mechanism of the body, and without the latter the uses of parts would be known by conjecture only. Harvey deduced from experiment proofs of the circulation of the blood, and almost every important addition to physiology has been obtained by the same method. It is to be hoped that no one can look without abhorrence upon deliberate or wanton cruelty: but who would brand with either reproach experiments calculated to determine principles directly or remotely of practical importance in medicine and surgery, or deny that they present an advantage to mankind, which may weigh against the attendant evil? He at least, who applauds on the principle of expediency the daily destruction of animal life for other purposes, cannot consistently impugn the moral feelings of those, who shrink not from inflicting pain on inferior creatures, in order that the sum of human suffering may be lessened.

The globe of the earth is formed of what are termed mineral substances, existing either in a solid, or in a liquid, or in a gaseous form. Upon or near its surface are found other bodies, which either live, or, being dead, preserve some remains of that shape and structure which they possessed during life. Living bodies are either plants or animals. The elaborate contrivances calculated for special ends or functions, which admit of being displayed in the greater number, have obtained for the whole the general appellation of organized bodies. On the other hand, mineral substances, which taken individually consist of mere aggregations of similar particles, are termed unorganized.

Mineral bodies are perhaps less correctly termed inert. The properties of unorganized matter produce in it continual changes, though of a kind less adapted to excite observation, than those which modify organized bodies.

The surface of the earth is perpetually undergoing alteration, through chemical action or mechanical attrition. The oxygen of the atmosphere is in constant consumption, and is constantly reproduced. The waters, which in various ways become polluted, are rendered pure at the time when by spontaneous distillation they rise in vapour, are again condensed, descend in the form of rain or snow, and becoming impregnated with atmospheric air, are again distributed over the earth to diffuse fertility and health; a combination of functions, which offer a rude type of respiration and of the circulation of the blood in animals. The properties of inert matter again determine the alternations of night and day, the recurrence of the seasons, the revolutions of the planets; a series of changes which may be termed the Life of the World.

In the preceding illustration of its meaning, the term "Life" is employed figuratively. In its direct sense it denotes other changes, which occur exclusively in organized bodies. The term "Life," like the terms "Nature" or "Mind," is a collective expression for an assemblage of phenomena. Each instance, that I have adduced, suggests parallel inquiries. Thus philosophers investigate the laws of life, the laws of the human mind, the laws of nature, by an analysis of the phenomena, which the terms, life, or mind, or nature, comprehend. In either instance, when certain antecedent circumstances are found to be invariably followed by a given change which ensues in no other case, the law or physical cause of that change is ascertained; and some general expression is made use of, which strictly, indeed, denotes no more than the invariableness of the sequence of events, yet figuratively appears to attribute causation to matter or to mind. The terms property and principle are commonly considered in natural philosophy equivalent to the term already used. Perhaps the following relative value may be assigned to each: the word law seems to express the conditions essential to a change: the word property, to attribute to a substance the power of producing a change under ascertained conditions; and the word principle, like the final letters of the alphabet in algebraic calculations, appears used to denote an unknown element, which when thus expressed is more conveniently analyzed. Consistently with the explanation given, we state, as the law of gravity, the ratio in which masses of matter are reciprocally attracted; or observe that masses of matter possess a property of reciprocal attraction; or we speak of the principle of electricity, or of the principle of magnetism, as the unknown causes of phenomena that are as yet imperfectly understood. Hitherto the laws of life, or the properties of living matter, have not been determined with precision; and physiologists are reluctant to disuse the vague term, "a Principle of Life," to which an imaginary value is assigned by many, who forget that all terms of this nature are but generalized expressions of facts, the efficient cause of which necessarily remains inscrutable.

But organized bodies are distinguished from mineral substances by their physical character, as well as by exclusively exhibiting the phenomena of life. Animals and plants are distributed in species, each of which has its limited bulk and peculiar form; mineral substances have no limit to their magnitude or variety of figure. The former are generally composed of dissimilar parts, the latter are homogeneous. The outline of the former is curvilinear, of the latter bounded by right lines. The former, which consist of materials produced in the laboratory of the living body by delicate combinations of mineral elements, are preserved by the vital influence alone; and as soon as life has ceased, slowly or rapidly revert to the condition of inert matter. The latter, which derive their character from chemical attraction or other causes of a permanent nature, have but little tendency to change.

The materials of which organized bodies are wrought, are termed their proximate principles. They may for the most part be obtained separately by very simple processes. Thus, if flour be formed into a ductile paste by the gradual addition of a small quantity of water, and the paste be kneaded by the hand and washed by a slender stream of water, it becomes a gray tenacious and highly elastic substance termed gluten. The water employed is rendered turbid and milky; the white matter suspended in it is starch. Gluten and starch are proximate principles in vegetable chemistry. When meat is boiled for a long time in water, oil is observed to separate and float upon the surface: another substance exists dissolved in the water, which becomes solid on cooling, and is termed gelatine: the tasteless shreds which remain are termed fibrin. These are proximate principles of animal matter.

Anatomy separates the human body into membrane and flesh, nerve and sinew, bone, cartilage, and the like; and shows in what order, figure and proportion, these parts are combined. The finer processes of chemistry distinguish in each of these parts the relative quantities of their proximate principles. A coarser analysis, as by destructive distillation, shows the bulk of carbon, oxygen, hydrogen, nitrogen, and other simple elements of matter, to the union of which the formation of each part is finally traced.

Thus, according to Thenard, the ultimate principles of the substances most used in the construction of the human body, that are formed exclusively through the vital influence, are the following:

	Carbon.	Oxygen.	Hydrogen.	Nitrogen.
Fibrin . .	53.365	19.865	7.021	19.934
Albumen .	52.883	23.872	7.540	15.705
Gelatine . .	47.881	27.207	9.914	16.988

The spontaneous decomposition of animal or vegetable matter has reference to the nature of its proximate principles. In many instances changes supervene, which have a tendency to retard complete resolution. Various sorts of fermentation furnish products remarkable for the length of time they may be preserved unchanged. Where nitrogen is present, as in most animal and in some vegetable substances, the process of decomposition, characterized by its rapidity, its fetor, and the extrication of ammonia, is termed putrefaction. Within a short time after death, the human frame undergoes an evident change; the features become sharper; the eye sinks; the neck and abdomen become discoloured; the body softens and exhales an offensive odour; the skin, from which the cuticle separates, turns successively green, and blue, and black; the corpse slowly dissolves, part combining with the atmosphere, part reduced to a liquid state, part mouldering to earth.

In order that putrefaction may take place, the body must be exposed to the conjoined influence of an elevated temperature, of moisture, and of atmospheric air, or air containing oxygen. If either of these agents be excluded, the progress of decomposition is arrested. Frozen provisions may be preserved indefinitely, with little change besides a diminution of their flavour. A dissected limb suspended in a current of air, loses its moisture by evaporation, becomes hard and of a brown colour, and subsequently remains for a length of time without undergoing further alteration. And the experiment has been found to succeed of preserving meat for many months free from taint, by inclosing it in metal cases accurately soldered.

Certain substances are termed antiseptic, with which when animal matter is impregnated, the ordinary mode of decomposition is prevented, and another change substituted; after which, any further alteration either does not ensue or is greatly retarded. Antiseptic substances are either of an aromatic nature, such as camphor, resins, volatile oils, and bitumens, which have been at various times employed in the process of embalming: or acids, sugar, certain neutral salts, as nitre and muriate of soda, which are principally used for culinary purposes, but some of which are serviceable in anatomy. A saturated solution of three parts of nitre and one of common salt, or of nitre alone, injected into the blood-vessels previously to dissection, appears almost wholly to neutralize that virus, by inoculation with which the life of more than one student is annually sacrificed in London. Of the substances that remain, alcohol, which when diluted produces less change than any other antiseptic fluid in the appearance of parts immersed in it, is peculiarly fitted for the preservation of anatomical preparations.

It would thus appear that animals and plants are characterized by their determinate bulk and figure, by their curvilinear surfaces, by their organized structure, by their chemical composition: finally, they are highly porous or tubular.

We may next consider what those changes are, which, exhibited for a period by all organized bodies, constitute life.

A body is said to be alive, when it exhibits or is capable of exhibiting the following phenomena.

1. The assumption of foreign matter into its substance, either received into a special cavity, or diffused generally through its porous or tubular structure.

2. An assimilation of this matter, through some change produced in the affinities of its elements, to the nature of the living being which contains it.

3. A deposition of the assimilated matter at different parts of the frame, in such a manner that it constitutes an integrant part of the plant or animal.

These changes, observed in all living beings, constitute nutrition. Other phenomena remain, which have not been proved to belong to all living beings, which in many are of partial occurrence, but which in the more perfect are supposed to be essentially coupled with the preceding.

4. A process of interstitial absorption, by which those molecules, which for a time have formed integrant parts of the living body, are removed.

5. A process, by which the re-absorbed materials, or such parts as are of no further use, are eliminated from the body.

6. A process, differing little in its nature from the

preceding, which consists in the separation of carbon from the body through the influence of atmospheric air.

7. An evolution of heat. Mr. Hunter found that a fresh egg, if frozen and thawed and again frozen, is seven minutes and a half longer in freezing the first time than the second: the first freezing, he supposed, destroys the life of the egg[a].

Growth by nutrition is characteristic of life; but to what extent an internal renovation is continually occurring, even in animals, remains problematical. Many parts in a living body once formed from assimilated matter, continue alive through their simple cohesion with organs in which nutrition is presumed to take place: and there are curious instances of organized bodies, in which every internal movement is suspended for a length of time, yet vitality remains. The seeds of plants and eggs of animals, if preserved from air and moisture and extremes of temperature, continue alive for months and years. The Vibrio Tritici, a minute animalcule which is the cause of the ear-cockles in wheat, when dried is to all appearance dead; but, after being kept for many days in this state, on being moistened, revives, and moves in a lively manner[b]. A leech frozen and gradually thawed, will sometimes live. A rabbit's ear frozen so as to chip, when thawed, bleeds, inflames and thickens, but lives.

Life is produced by a modification of that process which brings it to maturity. Generation in plants and animals is the formation of a germ, which in time becomes separated from the surface on which it grew and capable of independent existence. The millepede, a highly-organized animal, was observed by Trembley spontaneously to divide into two: upon the hinder part, which is a third of the length of the animal, a head is formed, to the fore part a tail [c]. The growth of a germ or embryo upon a definite surface in a plant or animal, and its subsequent separation, presents no feature that essentially distinguishes it from the preceding curious instance.

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[a] Hunter on the Blood, p. 79. [b] Phil. Trans. vol. cxiii. page 9.

Upon a strict analysis of the phenomena above enumerated, two properties, to which the whole appear referable, admit of being indistinctly shadowed out.

I. The change wrought upon the ingesta during assimilation, which appears strictly analogous to some effects of chemical attraction, may be ascribed to a principle of *Vital Affinity*. In order to give this term an equal value with the term gravity, physiologists have only to determine with precision the physical conditions, which invariably precede changes in the chemical nature of the ingesta and of the component elements of a living body. It is highly probable that the laws of chemistry, and the property, which controls the affinities of matter in living bodies, will prove eventually to be identical.

II. The assumption of foreign matter, and its propulsion through the tubes of a living body, may be partially produced or promoted by capillary attraction, by elasticity, by impulse communicated from without, by gravity: but in the majority of instances another principle is distinctly in operation. It is ascertained that various parts in animals and plants alternately contract and expand when alive; or at one time have a tendency to become shorter in one direction, at another to extend themselves to their former dimensions: this property is termed Irritability. The fluids in the higher animals are thus set in motion by the contraction of the vessels, which contain them. In the propulsion of the sap of plants, many phenomena prove that the same contrivance is used. It is analogically probable, that in all living bodies a like principle is employed upon this object. It remains for physiologists to determine the exact conditions, under which different irritable parts contract or are relaxed.

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[c] Mémoires pour l'Histoire d'un Genre de Polypes, p. 221.

To these simple properties the changes common to every mode of nutrition may be ascribed. No phenomena in vegetable life require the assumption of an additional principle. The movements observed in the mimosa sensitiva, in the muscipula dionæa, and in other plants, imply no agency which does not fall under the description of irritability. Upon a local irritation a part of a plant visibly contracts. Thus likewise upon the application of cold the human skin shrinks: or if the heart be taken from an animal directly after death, when pinched it contracts, or its fibres spontaneously continue to be shortened and elongated alternately.

Some have supposed that the discrimination shown in the growth of climbing plants towards objects fitted to support them, and in the direction which the roots of plants occasionally take towards a nutritious soil, implies the operation of a property analogous to instinct in animals. But it may be remarked, that if a plant grow at all, it must grow in one direction or another: and that if its growth take place upon principles at all resembling those of chemical changes, it is likely to be influenced by slight variations of moisture or temperature, by drafts of air, by light and shade, and the like; which are likely, in the cases referred to, to fall in different degrees on different sides of the growing plant: and that if it be found that phenomena similar to those in question distinctly result in well ascertained instances from physical impressions, it is more philosophical to attribute the production of the whole to the same cause, than to assume a second unnecessarily.

One of the most remarkable phenomena in the growth of plants is, that in whatever way a seed be laid in the ground, the elongated germen rises, the radicle descends. Upon the hypothesis that physical impressions determine growth, it would seem probable that gravity is in this instance the determining cause, or that the growth of the radicle necessarily follows the direction of an attracting force, that of the germen the reverse.

Mr. Knight ascertained this solution to be just, by an experiment in which another force was made to supersede that of gravity. Numerous seeds of the garden bean, which had been soaked in water so as to produce the utmost degree of expansion, were attached at short distances along the circumference of a vertical wheel, which by a current of water was made to perform more than 150 revolutions in a minute. In a few days the seeds began to germinate: the germen of each tended towards the axis of the wheel; the radicles grew in a contrary direction[d].

When animal life begins, new properties are added. The polype, which in material organization is infinitely more simple than the higher plants, gives proof of sensation, instinct, and volition: yet, when divided, each half grows into a perfect polype.

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[d] Phil. Trans. vol. cvi. p. 108.

In the ascending scale of animals, the phenomena of consciousness are more and more developed: the structure of the body becomes proportionately more elaborate: the animal becomes individualized: its separate portions are rendered incapable of independent existence: it consists of a single series of organs, the functions of which exert a reciprocal influence, and combine to sustain life.

It is usual to arrange the functions distinguished in the human œconomy under two heads; the vegetative or organic, the animal or sensitive.

By the former, nutritious matter is separated from the food, is conveyed through the lacteals into the veins, becomes blood, circulates through the body, contributes to growth; or component particles of the body are absorbed, thrown into the circulation, eliminated. The embryo is formed, fœcundated, grows to fœtal maturity, is born.

By the latter, the human being, through sensation, becomes acquainted with the external world, with social existence, is led to the instinctive gratification of his appetites, or on reasoning and calculation combines for definite ends a series of voluntary movements.

The preceding division, however, is not strictly applicable to the plan of a systematic work upon Physiology. Almost every function is partly sensitive, partly vegetative. Thus we discriminate the quality of food by sensation, and swallow it voluntarily to allay an appetite; but of its digestion we are unconscious, and cannot accelerate or retard it.

In this dilemma, it is obvious that the adoption of a very rigorous method is impracticable; or would serve to give about as clear a notion of life, as a separate description of the single threads in a piece of tapestry would of its design. Among the circle of functions it is difficult to determine with which to begin; and where selection is not easy, it is to be presumed that the advantages of different plans are so equally balanced, as to leave it a matter of small importance, which is chosen.

CHAPTER II.

OF THE BLOOD.

THE blood either is immediately supplied from the assimilated portion of the food, or consists of the old materials of the frame re-absorbed and a second time thrown into the circulation. From the blood are separated the substances of which the body is formed, as well as those which being noxious or unserviceable are to be eliminated.—An account of the properties and composition of the blood should therefore tend to elucidate the nature of the component parts of the human body.

The blood, distributed through every part of the system for its nourishment, becomes loaded with a principle, for the removal of which the influence of atmospheric air is necessary. The alternate flow of the blood through the body generally, and through an organ, in which it is exposed to the air, takes place in the following manner.

Upon the diaphragm, which is the floor of the chest, is placed the heart, a hollow fleshy viscus containing two cavities, one to the right of and before the other: each cavity consists of two chambers. Into the posterior chamber, or auricle, of each cavity veins open and transmit blood, which is thence propelled into the anterior chamber, or ventricle, of the same side, and from each ventricle into a capacious cylindrical vessel termed an artery.

The chest contains in addition the two lungs, elastic membranous organs, laid out in small cells, into which the windpipe opens. Atmospheric air is alternately drawn into and expelled from the air-cells of the lungs through an instinctive exertion of the respiratory muscles, which alternately enlarge and diminish the cavity of the chest.

The blood, which has been employed in nutrition, being mixed on its return from all parts of the body with the produce of digestion and of interstitial absorption, is carried into the right auricle of the heart by three venous trunks. From the right auricle the blood is forced into the right ventricle; from the right ventricle, into the pulmonary artery; which, dividing, sends a branch to either lung, to be distributed throughout its substance in ramifications so fine, that each air-cell is covered with minute capillary vessels probably not exceeding $\frac{1}{1000}$ of an inch in diameter. The air acting through an interposed membrane upon the blood contained in these minute tubes, removes its superabundant carbon.

It is supposed that capillary vessels no where terminate by open orifices, but that in the same ratio in which they are produced from the branching of arteries, they re-unite to form veins. The trunks of the pulmonary veins are commonly five in number; two of which issue from the left lung, three from the right. These five veins open into the left auricle, whence the blood which they have conveyed thither is propelled into the left ventricle; from the left ventricle into the arterial trunk of the body, the aorta, the branches of which are distributed as universally throughout the whole frame, as those of the pulmonary artery through the lungs alone. In the capillary vessels of the aorta the blood becomes loaded with carbon. The veins formed upon the capillaries of the aorta are finally collected in three trunks, the two venæ cavæ and the coronary vein, which open into the right auricle of the heart.

Such is the course of the blood, the discovery of which immortalized Harvey. His famous theory of the circulation was formed upon the following premises. 1. An animal may be drained of blood by opening either an artery or a vein. 2. If a ligature be placed upon an artery, blood flows with greater force from the vessel when punctured on the side nearest the heart, than when punctured upon the side remote from the heart: the contrary happens, if the experiment be made upon a vein. 3. The valves in the heart, the valves at the origin of the arteries, and in the veins, are so disposed as to prevent the blood flowing in any other direction than that above described.—Subsequent researches have added little to this conclusive evidence, beyond the fact that in transparent parts of living animals the blood may be seen to flow in a continued current from the arteries into the veins.

The blood contained in the pulmonary veins, in the left cavity of the heart, in the aorta and its branches, is of a scarlet colour, and is termed arterial blood. That contained in the veins of the body, in the right cavity of the heart, and in the pulmonary artery and its branches, is of a dark purple hue, and is termed venous blood.

Blood when flowing from a vessel of the living body is an unctuous liquid, of a faint odour and saline taste, of the temperature of 98° of Fahrenheit's thermometer, and of the average specific gravity of 1050. The extremes, between which the specific gravity of the blood was observed to range in the recent experiments of Dr. Scudamore and Mr. Wood, were 1039 and 1059: in the former instance the blood was drawn from a robust woman in health, in the latter from a man labouring under pneumonia, who had been previously bled four times[a].

Dr. Davy ascertained that the temperature of arterial blood in a living animal is about a degree higher than that of venous blood. The temperature of blood when flowing from the carotid artery of a lamb was found to be 105°, from the jugular vein 104°. In lambs killed by the division of the great vessels in the neck, the temperature of the left side of the heart appeared about 106°, of the right side 105.5°. In oxen that had been knocked down, the blood being of the same colour in the arteries and veins, the temperature of the arterial blood was found to be 101° or 101.5°; of the venous blood, 100°. In a sheep, in which the specific gravities of arterial and venous blood were 1049 and 1051, the relative capacities of the two fluids for caloric were as .913 and .903.[b] According to Dr. Scudamore, arterial blood in human beings is a degree warmer than venous blood, but exceeds it likewise in specific gravity. and

If venous blood be exposed to the influence of atmospheric air, it assumes a florid colour, with the properties of arterial blood; and the air, with which it has been in contact, is found to have lost a certain quantity of oxygen, and to contain in its place carbonic acid. As oxygen readily unites with carbon, and as the alteration observed in the qualities of the blood is such as might result from the loss of carbon, it is presumable that the preceding change consists simply in the transfer of this principle from the blood to the atmosphere.

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[a] Essay on the Blood, p. 36.

[b] Phil. Trans. vol. civ, p. 593, et seq.

When blood is detained in a vein its colour becomes darker.

If arterial blood be kept at rest in a vessel of the living body, it gradually acquires the properties of venous blood; as may be seen on slackening a tourniquet after an amputation, when the first blood that issues from the divided arteries is of a dark colour. If arterial blood be placed in vacuo, or be exposed to nitrogen, hydrogen, or carbonic acid, it loses its florid hue[c]. The blood has been found of a dark colour upon opening the temporal artery of persons labouring under the effects of opium. Extravasated arterial blood remains florid for several minutes; after an interval it is found to have coagulated, and to be of a dark colour.

Blood flowing from a vein has been observed, when fainting supervened, to lose its usual appearance, and to become of a florid hue[d].

A halitus is seen to rise from the surface of blood recently drawn, upon the same principle that a sensible evaporation takes place from other liquids when their temperature is elevated.

Blood that after having been drawn has stood a few minutes, is observed to be covered with a thin pellicle, and afterwards the whole quantity gradually becomes a gelatinous solid. This change is termed the coagulation of the blood. On an average it commences about three or four minutes after blood is drawn, and is completed in seven or eight[e]. Dr. Gordon found the coagulating portion of a quantity of blood warmer than the rest by

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[c] Thomson's System of Chemistry, vol. iv. p. 615.

[d] Hunter, l. c. p. 68. [e] Hewson's Experimental Inquiries, p. 25.

6° of Fahrenheit's thermometer. On repeating the experiment upon blood drawn from a person labouring under inflammatory fever, the rise of the thermometer was no less than 12°[f]. In the experiments of Dr. Scudamore, heat was found to be produced during coagulation, but in a less proportion. Mr. Brande ascertained that during the coagulation of the blood carbonic acid is disengaged; this appeared to happen to an unusual extent in blood drawn soon after a meal[g].

In a short time after coagulation, drops of a yellowish liquid are seen to exude from the clot, which thus spontaneously separates into two elements; the solid part is termed the crassamentum, the fluid part the serum of the blood. The crassamentum is usually estimated to be a little less in quantity than the serum. But according to Dr. Scudamore and Mr. Wood, the mean of twelve experiments gave 56.307 per cent of crassamentum. The proportion of serum is greater in persons of a debilitated habit of body than in those who are strong: it is greater again when coagulation takes place under a low degree of temperature[h]. The slow contraction of the coagulum is said not to cease till the fourth day.

Serum when exposed to a temperature of 160°, and still more readily at 212°, is converted into a white coherent mass, from which a fluid termed the serosity may be obtained by pressure. The coagulated part is albumen. The same principle exists in the serosity, but is suspended by the presence of an alkali. Atmospheric air in contact with serum does not lose oxygen and acquire carbonic acid, as when in contact with blood. The component parts of serum, according to Dr. Marcet, are—

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[f] Thomson's Annals, vol. iv. p. 139.

[g] Phil. Trans. vol. cx. p. 6.

[h] Ibid. vol. xcviii. p. 138.

Water	900.00
Albumen	86.80
Muriates of potash and soda .	6.60
Muco-extractive matter . . .	4.00
Subcarbonate of soda	1.65
Sulphate of potash	0.35
Earthy phosphates	0.60
	1000.00

The specific gravity of serum is 1028.

When the crassamentum has been repeatedly washed, it becomes a glutinous and fibrous mass of a grayish colour: the water employed is rendered red. The grayish substance is termed fibrin, and appears not to differ from the material left after the long boiling of muscular flesh. It forms the tough substance which is found after death in the cavities of the heart and great vessels, and in aneurysmal sacs, where it is disposed in concentric layers.

The colouring matter of the blood is connected with innumerable globular bodies, which are readily discerned with the assistance of a microscope upon examining serum, in which a portion of the coloured clot has been broken down. In a drop of blood the globules are too numerous to admit of their being distinctly seen, except along its edges, and there even for the most part the mutual cohesion of the globules gives them individually an irregular figure. Dr. Young describes the particles of the blood as having a slight depression in the centre, and as flattened to that degree, that their axis is sometimes not above one-third or one-fourth of their greatest diameter. Mr. Bauer represents each particle as strictly globular.

According to the measurement of Dr. Wollaston, the diameter of a globule of the blood is $\frac{1}{4900}$ of an inch. The mean of Captain Kater's observations gave $\frac{1}{5000}$[i]. Upon examining the globules of blood drawn in streaks across a glass micrometer, which was divided in squares of 250,000 to the inch, it appeared to me that where the globules best preserved their circular outline, a line composed of seven covered one side of a square; the side of a square was $\frac{1}{500}$ of an inch; the diameter of a globule by this measurement $\frac{1}{3500}$. Several lines $\frac{1}{500}$ of an inch in length, contained eight or even nine globules; but in these instances the globules appeared narrowed by lateral pressure.

Dr. Young mentions that the particles of the blood when placed in water lose their colouring matter, and with it much of their specific gravity[k]. Mr. Bauer describes the diameter of the coloured globules as $\frac{1}{1700}$ of an inch, and that of the globules reduced in size by the extraction of their colouring matter as $\frac{1}{2000}$ of an inch. The same observer describes a set of smaller globules, the diameter of which he estimates at $\frac{1}{2800}$ of an inch, that are discoverable in the coagula of old aneurysmal sacs. Globules of similar dimensions seemed to constitute the greater part of the size or uncoloured fibrin of inflammatory blood, and of the lymph thrown out by an inflamed surface; and were found to be produced spontaneously in serum kept for some time in a stopped phial[l].

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[i] Phil. Trans. vol. cviii. p. 198.

[k] Medical Literature, p. 573.

[l] Phil. Trans. vol. cx. p. 3.

Several of these remarks agree with the observations of M.M. Prévost and Dumas, who suppose the blood to consist primarily of coloured particles and serum, and represent the fibrin as formed of coherent globules which have lost their colouring matter[m].

Mr. Brande discovered that the colouring matter of the blood is an animal substance of a peculiar nature, susceptible, like the colouring matter from vegetables, of uniting with bases, and applicable to the art of dyeing. The most effectual mordaunts for the colouring matter of the blood are salts of mercury, especially the nitrate and corrosive sublimate.

Mr. Brande ascertained that iron does not exist in greater proportion in one element of the blood than in another[n].

The coagulation of the blood and its separation into serum and crassamentum are phenomena, which may equally be regarded as the result of its composition, with its previous continuance in a fluid state. The circumstances under which the blood exists vary, and the reciprocal attraction of its elements is changed. Our knowledge upon this subject is, however, very imperfect, and amounts but to a bare enumeration of instances, in which the coagulation of the blood takes place readily, or slowly, or is entirely prevented.

The tendency of the blood to coagulate, when drawn from the living body, is not affected by moderate differences in temperature[o]. Blood at 67° and 105° coagulates in the same time as at 98°: as readily[p] when exposed to azote, nitrous gas, nitrous oxide, carbonic acid, and hydrocarbon, as when exposed to atmospheric air[q].

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[m] Annales de Chim. et de Phys. tome xxiii. p. 50, et seq.

[n] Phil. Trans. vol. cii. p. 90.

[o] Hewson, l. c.

[p] Hunter, l. c.

Blood coagulates quickly when placed in a receiver, from which the air is immediately exhausted; when slowly drawn into a shallow vessel; when exposed to atmospheric air[r] at a temperature of 120°; more rapidly when the body is exhausted by hemorrhage, than when it exists in strength and vigour: the latter provision is remarkable, for the coagulation of the blood tends to stop hemorrhage. Upon the same provision is founded the practice of reducing by low diet and repeated bleedings those who labour under internal aneurysms, with the expectation that the sac may become obliterated, or its growth be retarded by the accumulation of layers of coagulum.

The coagulation of the blood admits of being postponed: 1. By freezing. A portion of the jugular vein in a rabbit tied between two ligatures was removed with the blood contained in it, and frozen: when thawed, the blood became liquefied, and coagulated[s]. 2. By low temperatures above the freezing point. Mr. Hewson placed blood in oil at a temperature of 38°: at the expiration of six hours it continued fluid; but being then allowed to attain a warmer temperature, it became coagulated in twenty-five minutes. 3. By mixture with certain neutral salts. If half an ounce of Glauber's salt be mixed with six ounces of fresh blood, the mixture does not coagulate; but on the addition of a double quantity of water coagulation takes place.

Other circumstances delay coagulation. Blood coagulates slowly when drawn rapidly into a deep vessel; when taken from a person in vigorous health, or from one labouring under inflammation; when detained at rest in a vein of a living animal between two ligatures. On a repetition of the last observation, Mr. Hewson found the blood two-thirds fluid after three hours and a quarter had elapsed: the blood being then exposed, entirely coagulated. When the experiment was varied by blowing air into the vein, the blood was found to have coagulated in a quarter of an hour. Mr. Hunter mentions that two leeches which had been applied, were subsequently preserved ten weeks. At the expiration of that time they contained a considerable quantity of blood, which appeared like blood recently drawn from a vein, and coagulated when exposed. The following incident is to the same purpose. On tapping a hydrocele, a small vessel was wounded, and the blood escaped into the sac: when the tapping was repeated sixty-five days after, the blood came out thickened, but then coagulated and separated into different parts[t]. Blood, extravasated through the rupture of vessels, often remains for a considerable time in a fluid state.

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[q] Researches on Nitrous Oxide, by Sir H. Davy, p. 380.

[r] Dr. Scudamore's Essay on the Blood.

[s] Hewson, l. c.

In some instances a modified coagulation takes place. Mr. Hewson found that if blood was kept at a temperature of 38° for twenty-four hours, it had become thick and viscid, but did not coagulate on regaining a higher temperature. In torpid bats Mr. Cornish found the blood thickened, but it soon recovered its fluidity on motion and heat.

The blood does not coagulate when the causes that are capable of postponing coagulation have continued to operate beyond a certain period. If recent blood be constantly stirred for some minutes, it remains permanently fluid. In persons killed by lightning, by blows on the stomach, by the bite of venomous serpents, or through the influence of acrid vegetable poisons, or in persons dying from violent mental emotion, the blood is said to be found fluid, and the muscles do not become rigid. A temporary change in the nature of the blood, of a like kind, is found in certain diseases. Mr. Hewson mentions that a woman was bled in a fever which came on soon after delivery: her blood did not coagulate on being exposed to the air, but appeared like a mixture of the red globules and serum only, the globules having subsided to the bottom in the form of a powder. She died three days after; and upon examination the blood was found to have coagulated in the vessels, and a tough white clot was found in each auricle of the heart: the blood that had been taken during her life did not coagulate till at the heat of 160°. The blood secreted in healthy menstruation does not coagulate.

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[t] Hunter on the Blood.

It is remarkable, that, if we except the effects of extreme cold, the causes which seem to retard the coagulation of healthy blood, when not circulating in the body, are the presence of one or other of two conditions essentially belonging to it when circulating in its proper vessels, motion namely, and the exclusive contact of living surfaces. Of these conditions, if motion be not the most influential, yet if it be wanting, coagulation occasionally takes place even in the living body, as is shown by the clots formed in aneurysmal sacs, and in arteries to which ligatures have been applied.

Blood when coagulating is remarkably adhesive, and readily attaches itself to a cut surface, or to an internal membrane of the living body. Mr. Hunter ascertained that the clot of blood adhering to the edges of a wound becomes vascular, or receives fluid blood from the living surface into a series of irregular cavities. Mr. Hunter succeeded in injecting the adherent coagulum from the arteries of the neighbouring parts.

Sir Everard Home has recently ascertained that the tubular cavities of the clot are spontaneously formed in it, whether in contact or not with a living part, unless the blood coagulate in an exhausted receiver. He attributes their production to the disengagement of carbonic acid [u]. The adhesive property of coagulating blood, and its capacity of becoming organized, make it highly instrumental in re-uniting divided parts of the living body.

During derangement of health, the blood exhibits various peculiarities.

The serum has been found to have the appearance of whey; to have streaks upon its surface like a cream; to have been as white as milk, the coagulum retaining its usual appearance. Mr. Hewson, who considered the red particles of the blood to be flattened, attributed the colour of the serum in the preceding instances to the presence of very minute globules. Mr. Hunter observed the serum in one case separate from, and swimming upon, the uncoagulated fibrin immediately after the blood had been drawn; and mentions that in jaundiced persons the serum is yellower than ordinary.

The crassamentum is sometimes found straw- or size-coloured, and semi-transparent to a greater or less depth upon its upper surface. This appearance is termed the buff, or, from its ordinary cause, the inflammatory crust of the blood. In general the sizy part is firmer than the rest of the clot, and its edges are drawn inwards so as to render the upper surface concave, which is then said to be cupped.

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[u] Phil. Trans. vol. cviii. p. 200.

It is not easy to say by what internal arrangement of parts the colourless size is produced: for although it be true that inflammatory blood coagulates more slowly than healthy blood, yet it is known from the experiments of Mr. Hewson, that neither the serum nor the coloured particles of either sort of blood differ in specific gravity; that healthy blood when slow in coagulating does not form a size; and that inflammatory blood in half a minute after it is drawn, exhibits a blueish transparency upon its surface, which shows that already the colour of the upper part is discharged. The lower part of a mass of inflammatory blood is found to be the first to coagulate; the colourless part is the latest in becoming coherent.

The rapidity, with which the healthy and inflammatory appearances of the blood may alternate, is very remarkable, and well illustrated in the following case.

A young man of an athletic habit was bled during a febrile attack. Upon opening a vein the blood flowed very slowly, or merely trickled down his arm: this appeared to result from the timidity of the patient; for after closing the wound for a few seconds and encouraging him, upon removing the finger the blood flowed copiously. Three ounces were then received into a second cup; an equal quantity was immediately caught in a third cup. The patient now became faint, was laid upon the floor, and a few drachms more of blood were taken into a fourth cup.

Of these four quantities of blood, that which was taken away the last was coagulated in three minutes; that first taken was coagulated in twelve; that taken in the second cup was not completely coagulated in twenty-two minutes; neither of the three had an inflammatory crust. But the blood received into the third cup began in five minutes to appear transparent on its surface, was not completely coagulated for thirty-five minutes, and exhibited a remarkably thick and tough size[x].

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[x] Hewson, l. c.

CHAPTER III.

OF MUSCULAR ACTION.

Various textures in living bodies are observed to exist at successive periods in two different states, to be at one moment elongated, at another shortened. The change from the one state to the other is the beginning of motion. The phenomena of each case, in which motion is thus produced, have common points enough to authorize us in ascribing the whole to one property, which has been termed Irritability. They are broadly distinguished from the effects of elasticity, of gravity, from the expansions and contractions of bodies, which are caused by changes of temperature; and although they in some respects correspond with the results of galvanic agency, yet the analogy seems far too loose and incomplete to warrant a conjecture that the movements of irritable parts depend upon a modification of the electric principle.

The parts of the human frame which possess irritability are, muscular substance, the substance of the uterus, the fibrous coat of arteries, the unattached margin of the iris, some parts of the skin, and perhaps the dense texture which is employed in forming excretory tubes. In the phenomena of muscular action alone, which form the subject of the present chapter, a surprising diversity exists.

Muscular substance is what is commonly called flesh in animals; varying in different genera and species, in different individuals of the same species, in different parts of the same body, both in firmness and colour, it uniformly preserves a more essential point of resemblance in its fibrous structure. Yet it may be remarked, that the firmness and depth of colour of muscles, taken relatively, are generally proportionate to the frequency and energy with which they have been used.

The flesh of the human frame is of a reddish brown colour in the muscles of the trunk, head, and limbs, and in the heart; of a pale gray in the muscular coat of the alimentary canal and of the bladder. But upon maceration in water it is found in each case to be reduced to little more than a colourless fibrin. The water that has been employed contains albumen, gelatine, extractive matter, and various salts. Perhaps the most remarkable circumstance, which chemistry has ascertained in this investigation, is that nitrogen exists in larger proportion in the muscles of animals with red blood, which possess the greatest variety of function, and enjoy them in the most perfect state, than in those of fish or reptiles; and that in animals of the same species, those of adult age contain more nitrogen than the same muscles soon after birth[a]. In young animals, it appears that the muscles as well as the membranes and bones contain a considerable quantity of gelatine; but as they advance in age the gelatine disappears, and is replaced by albumen. Fat, or oil contained in delicate membranous cells, is found in the substance of muscles, more coarsely wrought into the texture of some than of others, and in age than in youth.

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[a] Bostock's Elementary System of Physiology, vol. i. p. 152.

When a portion of a muscle is examined, it appears to consist of flattened bands, or lacerti, of a soft yielding flesh, connected together by a thin elastic transparent membrane. Each of these bands admits of separation into slender strips or fibres, which again may be resolved into others yet finer. All the fibres are individually invested and joined together by processes of the same membrane, which unites the lacerti.

A few hours after death the membrane investing muscles is found to be firmer and more adherent than at a later period. When decomposition commences, a moisture is produced between the membrane and the flesh, probably through the resolution of the finer productions of the membrane. If in this state a lacertus be laid upon a piece of glass and be partially drawn asunder into shreds under a drop of water, fine fibres of different sizes are visible every where to the naked eye. If the portion spread out to the greatest tenuity be examined in a microscope, the fibres at one part or another are distinctly seen to consist of numerous minute threads of an uniform size. As these threads appear to admit of no further subdivision, it is presumable that they constitute the primary filaments of muscular substance.

In order to obtain a coarse measurement of the diameter of these filaments, thin streaks of blood may be drawn at random across the prepared surface; and it cannot fail of happening that at one point or another the globules of the blood will be so intermingled with the isolated filaments, that their relative breadth may be compared. The diameter of a globule of the blood appears to be nearly the same with the breadth of the primary filament of a muscle.

If the primary filaments be now viewed under a varied light, by altering the inclination of the mirror attached to the microscope, or by shading the light with the hand, another circumstance becomes apparent at one point or another of the surface: the filament, instead of presenting a perfectly even outline, is seen to be regularly indented, and faint cross shadows upon its surface, more or less clearly distinguishable, show that it consists of cohering sphericles, which are nearly equal in size to those of the blood.

By the preceding method it is easy to obtain an approximation to the relative size of the muscular globules and of those of the blood, the discovery of which we owe to Sir Everard Home and Mr. Bauer.

The accurate observations of Mr. Bauer have determined that the size of the muscular globule exactly corresponds with that of the uncoloured globule of the blood; and that the primary filament consists of a series of such globules connected by an elastic medium, which admits of sufficient elongation that a visible interval may be produced between the globules[b].

It appears that in each fibre the primary filaments extend individually its whole length, and are laid parallel to each other. In different muscular parts the fibres are disposed in various ways, either parallel to each other, or convergent, or interwoven with and decussating each other.

Muscular parts receive a large supply of blood; but there is reason to believe that the distribution of the vessels is not so minute as former theories of nutrition supposed. The veins in muscles have numerous valves. Lymphatics have not been traced to any distance into the substance of muscles.

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[b] Phil. Trans. vol. cxvi. p. 5.

Nerves are distributed to all muscles, but in a larger proportion to some than to others, to the voluntary than to the involuntary: the observations of MM. Prévost and Dumas made it would seem upon parts of the former class, have elucidated a question, upon which hypotheses very opposite to truth were till lately entertained, and tend to establish the curious fact, that nerves are not continuous with muscular fibre. According to the statements of these physiologists, the course of a nerve and of its first branches through a muscle is in tortuous lines, the direction of which appears indifferent; but the minute filaments, in which each branch ends, are observed invariably to traverse the muscular fibres at a right angle and at short distances from each other, and then either to return to the same nerve, or to join a neighbouring branch: thus a nerve terminates in muscles by innumerable delicate loops, or the nervous filaments distributed transversely through muscular substance, communicate equally at either end with the brain or spinal chord. This disposition of parts is not to be observed without difficulty in the opake flesh of warm-blooded animals, but is readily seen in the thin transparent muscles of frogs. Several partial instances of a like nature have been long known to anatomists. The branches of the portio dura are found to unite by slender twigs with those of the three divisions of the fifth nerve in the flesh of the face; and in the tongue the union is equally evident of twigs of the ninth nerve with twigs of the gustatory. It is remarkable that in these familiar instances the junction takes place of sentient nerves with nerves of motion. MM. Prévost and Dumas have not ascertained whether the same relation is observed in the union of the ultimate nervous filaments in muscular substance[c].

All muscular parts during life or shortly after death, may be observed in one of two conditions, which alternate, in action or in repose, in tension or in relaxation.

A muscle, when relaxed, is soft, yields readily to lateral pressure, is easily extended in the line of its fibre, and if previously shortened, on becoming relaxed has a greater or less tendency to lengthen itself, which may possibly depend upon its elasticity alone.

A muscle, when in action, is hard, rigid, resists extension, and has a forcible tendency to shorten in the length of its fibre. The rigidity has no reference to the degree of shortening produced, but depends entirely upon the force employed. If with the elbow slightly bent, and the fore-arm in extreme pronation, an attempt be made against a superior resistance, to bring the arm into the state of supination, the biceps flexor cubiti without shortening becomes harder and more rigid than in extreme flexion of the elbow and supination of the wrist sustained without much effort. The shortening of muscles is an accidental result of their action.

Action may be produced in all muscles during life or soon after death by various stimuli; by mechanical irritation, as upon the simple contact of a new surface, or upon cutting, tearing, or pinching the exposed fibre, by chemical excitement, as upon the application of diluted acid or alkaline fluids, and of most neutral salts, or by electricity.

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[c] Majendie, Journal de Physiologie, tome iii. p. 303.

A muscle in action, if allowed to become shorter, gains exactly in thickness what it loses in length. The ventricular portion of the heart removed from a large dog immediately after death by hanging, was immersed in warm water contained in a glass vessel, which was closed below with a ground glass stopper, and terminated above in an open vertical tube one-third of an inch in diameter. The ventricles continued alternately to contract and dilate for a sufficient length of time to satisfy me that the height of the water in the tube was unaffected by the varying condition of the muscular fibre[d].

The change in form, which muscular fibres assume during their action, was remarked by the accurate and sagacious Hales.

"If," says he, "the skin be removed from the belly of a live frog, and the abdomen opened on each side so as that its straight muscles may by drawing a little on one side have a strong focal light cast on the inside of them; if in this posture these muscles be viewed through a good microscope, the parallel fibres of the muscles are plain to be seen, with the blood running alternately up and down between each fibre in capillary arteries so fine that only a single globule can pass them. If the muscle happens to act while thus viewed, then the scene is instantly changed from parallel fibres to series of rhomboidal pinnulæ, which immediately disappear as soon as the muscle ceases to act. It is not easy to get a sight of this most agreeable scene, because that on the action of the muscle the object is apt to get out of the focus of the microscope; but those who are expert in the use of these glasses may readily move them accordingly. I have found small frogs best for this purpose, namely such as are not above a third or a fourth of their full growth. Stimulating the foot of a frog will sometimes make it contract these muscles. The frog must be fixed in a proper frame. If repeated observations were made on the muscles thus in action, it might perhaps give some farther insight into the nature of muscular motion[e]."

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[d] Anatomical and Physiological Commentaries, vol. i. p. 12.

The recent researches of MM. Prévost and Dumas have supplied what was wanting in the observations of Hales, and explain the change in form of each single fibre, from which the preceding appearance results. The ventral muscle of a frog so placed in a frame that a current of the galvanic fluid might at pleasure be directed through it, was examined in a microscope. When excited to contract, the fibres were seen to become bent at numerous angles into zigzag lines. When the stimulus was discontinued, the part regained its former length, and the fibres their straight direction. The angles were observed to be placed at nearly equal distances, and corresponded exactly with the point of intersection of nervous filaments. The same circumstances are stated to have been made out in the muscles of warm-blooded animals, and no less in the muscles of the trunk and limbs than in those of the hollow viscera[f].

Dr. Hales expected to find in the circulation of the blood the cause of muscular action. The nervous influence is the idol of the present day; and MM. Prévost and Dumas trace the force of irritability to this source. Two currents of galvanic fluid moving in the same direction have a mutual attraction: in like manner, say these ingenious physiologists, two currents of the nervous influence (which they seem to identify in this instance with galvanism) or the nervous filaments, which are its conductors, may attract each other. This fanciful supposition, which removes the force of a muscle from its fibre to its nervous filaments, is curiously consistent with the fact, that the only apparent change in the muscular fibre when acting, is its zigzag flexion at those points where it is intersected by nerves.

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[e] Hales's Hæmastatics, p. 59.

[f] Majendie, Journal de Phys. vol. iii. p. 301, et seq.

When the ovary of the frog is full of spawn, the abdominal muscles are extended considerably beyond their habitual length. Upon being detached from the body, when in this condition, they are found to lose at once a third of their accidental elongation: but during this shortening the fibres preserve their straight direction; and only when subsequently excited by galvanism to further action, exhibit the phenomena above described, or become shorter, and are thrown into zigzag lines. The observation has equal interest, whether the first contraction be referable, as MM. Prévost and Dumas are inclined to suppose, to the elasticity of muscular substance, or require to be otherwise explained.

Many phenomena of the same description have been noticed, which are said to result from the tone of muscular parts. If a muscle in its medium state of extension be exposed immediately after death, as for instance, the pectoral muscle in a dog, and be divided transversely, the separate portions instantly recede to some distance from each other. The same happens in the living body; and as Bichat ascertained, the retraction is equally prompt and energetic, whether the nerves of the part have been previously cut through or not. The separate portions that have retracted, if excited, shorten further, and again become elongated to their last dimension. It is extremely difficult to determine whether the contraction in the first instances adduced, and the elongation in the last, belong to elasticity or to irritability: two remarks, however, may be made in connexion with this question. Muscular substance in the dead body appears to have but little elasticity; and wherever a muscle is found, some special provision is met with calculated to elongate it when relaxed, consisting either in an elastic resistance, or in the pressure of accumulating fluids, or, as more generally happens, in the action of other muscular fibres disposed as and termed antagonists to the first. In most cases two sets of muscles, which habitually antagonize each other, are yet capable of acting in concert.

By the excessive action of muscular parts, their irritability is said to become exhausted. By protracted exercise the voluntary muscles are consciously enfeebled. A muscle repeatedly stimulated in a physiological experiment at length ceases to act. Dr. Wilson Philip ascertained that this mode of exhaustion ensues even sooner when the part is left in communication with the brain, than when its nerves have been previously divided[g]. After unusual exertion, a period of repose seems requisite to enable a muscle to recover its full capability of contracting upon excitement. Sir A. Carlisle discovered that in several animals, which are remarkable for the slowness of their muscular movements, the main artery of each limb is abruptly divided into numerous trunks, which pursue a parallel course and freely communicate. In the fore leg of the lemur tardigradus, as many as sixty brachial arteries are thus found[h]. One effect of this provision must be to lessen the force of the blood circulating in the muscles of the limbs; but its relation to the habits and muscular power of the animal is unknown. In this, as in other instances, we are wholly unacquainted with the qualities in the organization of muscles, which diversify their mode of irritability.

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[g] Experimental Inquiry, p. 100.

The rigidity of muscles, which ensues soon after death, should tend to elucidate the nature of their action during life. The period at which this change begins, as well as its degree and the term of its continuance, are very indefinite, but appear to have some proportion to the degree of physical exhaustion which the body has previously undergone. The muscles of those killed by lightning are said not to become rigid. In animals that have been hunted or driven hard before slaughtering, the muscles are said to stiffen in a few minutes; but the rigidity is incomplete, and disappears sooner than in other cases.

In sheep and oxen the joints have ordinarily begun to stiffen in half an hour after death: in about twenty-four hours the rigidity appears complete, and the flesh when divided does not retract: but it seems that during the first three or four days it continues gradually to acquire more firmness. In hot weather the flesh of slaughtered animals never becomes perfectly rigid, and till decomposition begins, retracts in some degree when divided. Warmth appears directly to prolong the phenomena of irritability in dead muscular parts. A heart that has ceased beating will even resume its action when immersed in warm water. It may be observed, that under circumstances nearly similar, like parts in different animals of the same species vary remarkably in respect to the duration of their irritability after death. In two cats destroyed by hanging, the heart of the one had entirely lost its irritability in half an hour; in the heart of the other the auricles continued, at the expiration of four hours, occasionally to contract. In one instance the voluntary muscles, in another the involuntary muscles, first lose the capacity of being excited by stimuli. If the surface of the flesh be exposed within a few minutes after death, the fibres are seen to describe a right line, unless their attachment be brought near to each other, when they lie in folds: after a minute or two, slight convulsive actions are to be remarked of the separate fibres, both in the heart, and in the muscles of the trunk and limbs: these last for a few minutes, and are capable of being re-excited if salt be sprinkled upon the surface. Rigidity is produced almost instantaneously if warm water be injected into the arteries of a muscle. The flesh under these circumstances becomes pale, increased in bulk, and suddenly hardens.

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[h] Phil. Trans. vol. c. p. 99.

The operation of crimping fish consists in dividing the muscular fibre before it has become rigid, and immersing it in hard water. A small part treated in this manner, contracts and hardens within five minutes; a larger part takes a longer period. Sir A. Carlisle ascertained that crimped flesh gains in weight and in specific gravity, and mentions an experiment which is highly interesting, as anticipating in some degree and confirming the recent researches of M.M. Prévost and Dumas. Some of the smallest fasciculi of muscular fibres from a calf that had been killed two days before, were placed upon a glass plate in the field of a powerful microscope, and a drop of water thrown over them at the temperature of 54°, the atmosphere in the room being 57°: they instantly began to contract, and became tortuous[1]. Crimping only takes effect if performed before the natural stiffening has been completed. Sea-fish intended for crimping, are usually struck on the head when caught, which is said to preserve them for a longer period fit for the purpose. No doubt this expedient, which is fortunately humane, operates by preventing the fish from exhausting its muscles in convulsive efforts.

The preceding details illustrate generally the nature of muscular action. A muscle is, it appears, so constituted, that upon a given impression certain points in each fibre are suddenly attracted towards each other with increased force. It remains to be shown whether the attraction be exerted equally by every integrant molecule of the fibre, or whether it operate from definite points at appreciable intervals. Either supposition appears compatible with the change from the right line to a zigzag, which is observed to take place when the fibre is shortened beyond certain limits.

Muscular parts are found to vary among themselves, as regards their natural condition in the absence of special impressions, the duration of their action and of the alternate periods of repose which they require, the kind of stimulus calculated to excite their action, and the degree of sensation attending their use.

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[1] Phil. Trans. vol. xcv. p. 24.

When we seek for some broad and leading distinction among parts of this nature, a phenomenon presents itself, which serves to distribute the different modes of irritability under two heads. It is to be understood that every voluntary muscle receives a nerve, upon the division of which its action is paralysed: nerves of this class are sometimes called voluntary nerves. Now it is found that after a voluntary nerve is cut through, either in a living animal or immediately after death, mechanical irritation of the part of the nerve so disconnected with the brain, as for instance the pinching it with forceps, causes a single sudden action of the muscle or muscles it supplies. But this phenomenon is not confined to parts that are by common consent allowed to be voluntary; nor is it shown in all parts, which seem at first sight to be directly under the controul of the will. On the other hand, parts exhibit a like phenomenon which the will does not consciously actuate; and those which are commonly termed involuntary, show nothing resembling it. Setting aside therefore for the present the question of the influence of the will, let us be satisfied with observing what muscles act when a divided nerve that enters their substance is pinched, and what do not, and with tracing the collateral differences of the two classes of muscles, which are thus distinguished.

The parts which are susceptible of this mode of excitement, are the muscles of the trunk, head, and limbs, of the tongue, of the soft palate, of the larynx, of the pharynx and œsophagus, and of the lower outlet of the pelvis. The opposite class comprehends the heart, the stomach, the small and great intestines, and the bladder.

The collateral differences, which characterize either class, are, with exceptions afterwards to be adverted to, the following.

Of the muscles, which act when a nerve distributed through them is mechanically irritated, it may be remarked,

1. That they admit of being thrown into action by an effort of the will.

2. That with sufficient attention and resolution, their action may be refrained from.

3. That their action is attended with a conscious effort, and has reference to sensation.

4. That if divided, the separate parts retract instantaneously to a certain point, and subsequently undergo no further permanent shortening.

5. That when mechanically irritated, a single and momentary action alone ensues.

6. That they remain relaxed, unless excited by special impressions, both in the living body and before the loss of irritability after death.

7. That their action in the living body habitually results from an influence transmitted from the brain, or spinal chord through the nerves.

The exceptions to be made against this statement, if applied generally, are that the three first affections are not easily brought home to the muscular fibres of the œsophagus, or of the lower part of the pharynx; but it deserves at the same time to be considered, that the lower part of the pharynx and the œsophagus are in the peculiar situation of parts employed upon one object alone instinctively and habitually on the occurrence of a local sensation; a condition which would soon reduce a strictly voluntary muscle to a state apparently removed from the controul of the will.

Muscles of the preceding class, if we except the fasciculi belonging to the pharynx and œsophagus, and urethra, are so disposed as to extend from one piece to another of the solid framework of the body: they enlarge or straighten the cavities of the trunk; they produce the phenomena of the voice; they close the excretory passages; they move the limbs upon the trunk; the whole frame upon the ground. Muscles of the following class are employed, like the exceptions in the preceding, as tunics to the hollow viscera, the cavities of which they diminish in their action, and thus serve to propel their contents. The œsophagus, indeed, appears to partake of the nature of both classes of muscles; when the nervi vagi are pinched, one sudden action ensues in its fibres, and presently after, a second of a slower character may be observed to take place.

Of the muscles which do not act upon the mechanical irritation of any nerve distributed through them, it may be remarked,

1. That the will cannot instantaneously or directly produce action in them.

2. That efforts of attention, with the resolution to abstain from their action, are insufficient to repress it.

3. That their action is not attended with a conscious effort, and seldom has reference to sensation.

4. That if divided, the retraction which follows is in most instances slow and gradual.

5. That if they are mechanically irritated, not one, but a series of actions ensues.

6. That their natural state in the absence of external impressions is not continued relaxation. When the heart and bowels are removed from the body of an animal immediately after its death, they continue for a time alternately to contract and to dilate.

7. That an impression transmitted through the nerves does not appear the usual stimulus to their action.

The exceptions to be found to these remarks, are more numerous than in the preceding class, and their consideration would lead me into details too minute for this part of the work, in which my object has been to convey a general notion only of muscular action. Let me conclude the present chapter by observing, that the leading distinction pointed out among different modes of irritability appears applicable to other textures, besides those which are strictly termed muscular. The iris acts when one of the two nerves distributed to it is mechanically irritated. And on the other hand, the calibre of arteries is not diminished when their nerves are pinched; and the uterus and the skin, it is probable, are equally insensible to this mode of excitement.

CHAPTER IV.

OF THE FORCES WHICH CIRCULATE THE BLOOD.

The stream of florid blood, collected from innumerable vessels in the lungs, flows to every part of the body. The stream of black blood collected from the capillary vessels of the whole body, flows again into the lungs. The former passes through the left cavity of the heart, the latter through the right. The structure of the heart is muscular; its action gives motion to the blood, which by the operation of valves is confined to one direction.

But in order to understand the mechanism of the circulation, it is necessary not merely to examine the disposition of the muscular lacerti and of the valves in the heart, and the structure and properties of arteries and veins, but in addition to consider the nature and influence of the cavity in which the heart is placed, and of the dilatable and elastic viscera with which it is surrounded.

The thorax of a skeleton is a hollow conoïd, broad below, narrow above, where it is obliquely truncated: its axis is inclined obliquely upwards and backwards: it is composed of the dorsal vertebræ, the ribs, and the sternum. The twelve dorsal vertebræ form a column so bent as to be concave forwards, and which in reference to changes of figure in the chest may be considered as fixed. The twenty-four ribs are individually moveable upon the spine in every direction, but to a degree extremely limited. The seven uppermost, or the true ribs on either side, are let in by slips of cartilage into oval fossulæ along the side of the sternum, which they support. The five lower, or false ribs, are attached each to that above. The ribs and sternum are slight and fragile bones. In composition they derive strength from their convex form, and numerous and elastic joints.

An imaginary plane carried through the first dorsal vertebra, through both articular extremities of the first rib of either side, and through the upper part of the sternum, would slant obliquely downwards and forwards. By the movement of each first rib upon its spinal joint sufficiently to raise the upper margin of the sternum to the height of the first dorsal vertebra, the imaginary plane would become horizontal. In man this motion of the first rib is very limited; but it is obvious that in proportion as it takes place, the vertical distance of the sternum from the spine, or the depth of the chest becomes increased. The six lower true ribs move more freely upon their vertebral joints, and contribute to raise and carry forward the middle and lower part of the sternum for the same purpose.

By this provision all the muscles of the trunk, the lower attachment of which is to the ribs, are rendered capable of increasing the depth of the chest or its diameter from before backwards, and the opposite class of muscles, of diminishing the area of the chest in the same dimensions.

All the ribs, but the first, admit of a limited degree of rotation upon their vertebral and sternal joints. Nature distinguishes in the fœtal state the fixed character of the first rib, by forming its cartilage of a common substance with the sternum, with which the cartilages of the succeeding ribs are not continuous, and by disposing all its parts in one plane. If an oblique plane be imagined to pass through each articular surface of any pair of ribs between the second and tenth inclusively, the greater part of the shaft and cartilage of these ribs is seen to fall below it. If the intermediate part of these ribs be raised towards the imaginary plane by the rotation of each upon its sternal and vertebral joints, it is obvious that the transverse diameter of the chest becomes increased.

By this provision the same muscles, which contribute to enlarge the depth of the thorax, are rendered capable of adding to its breadth, and the same which diminish its area in the first dimension, are fitted to diminish it in the second.

The chest is closed above by a fascia or layer of condensed cellular membrane, which extends across from the spine to the sternum, from the first rib of one side to the opposite, and is perforated by the windpipe, the gullet, and the great vessels of the head and upper extremities. The intervals between the ribs are closed by the oblique fibres of the intercostal muscles, which in their action draw towards each other adjoining ribs, and are capable of contributing either to the enlargement or to the diminution of the area of the thorax.

The floor of the chest is formed by the diaphragm, or muscular partition, which separates it from the abdomen.

The diaphragm consists of three parts. 1. Of a central thin tendon of the shape of a trefoil leaf, of greater breadth than depth, which, although in a degree concave downwards, yet may be regarded as spread out horizontally at the level of the ninth dorsal vertebra, or of the lowest part of the fifth rib. 2. Of muscular fibres derived from the anterior and lateral margins of the tendon, which slope downwards to be inserted into the ensiform cartilage and into the inner and lower part of the seven lowest ribs, and are called the greater muscle of the diaphragm. 3. Of muscular fibres, which descend from the posterior edge of the centrum tendinosum to the lumbar vertebræ, and are called the lesser muscle. The diaphragm gives height by its action to the cavity of the chest. Under ordinary circumstances the diaphragm is raised to that degree, that the margin of the greater muscle is held, except at the back part, against the six or seven lower ribs, which therefore protect the viscera of the abdomen, not those of the chest. The diaphragm gives passage to different tubes and nerves; and it is remarkable, that while the œsophagus, the aorta, and thoracic duct pass through muscular apertures, the pressure of which they are calculated to resist, the great ascending venous trunk passes through an opening in the central tendon, with the margin of which its substance is interwoven, so that the vein is held open by the whole tonic force of the greater and lesser muscle.

The abdominal muscles are the antagonists of the diaphragm, which upon becoming relaxed admits of being raised by their lateral pressure upon the bowels.

In the cavity of the chest, thus amply furnished with the means of alternate expansion and diminution, are placed the lungs, one on either side, with the heart between.

A lung is an organ composed of a light cellular flesh, fitted to the varying form of the lateral part of the chest by its original figure and by its great elasticity, and adherent by a part of its inner surface, at which blood vessels and nerves, lymphatics, and a branch of the windpipe, enter. Each lung is covered by a fine transparent membrane termed a pleura, which is reflected from the adherent part or root of the lung towards the sternum anteriorly, towards the spine behind; and afterwards lines the diaphragm, the ribs, and intercostal muscles.

The pleura is one of a class of parts termed serous membranes: these are for the most part closed sacs, one half or one portion of which forms the investing tunic of a viscus, while the other is attached to the parts adjoining. The outer surface of a serous membrane coheres with the cellular texture of the organs, which it covers: the inner surface is unattached, and kept moist with a fluid resembling the serum of the blood. Serous membranes are employed to facilitate the movements of viscera upon the neighbouring parts by the interposition of two lubricated surfaces, and to isolate adjacent organs from one another. Sometimes there is a difference in the character of the visceral and reflected portions of a serous membrane. In the present instance there is none: but the pleura covering the lung is termed pleura pulmonalis, the reflected portion pleura costalis, pleura diaphragmatica, or pleura pericardiaca, in reference to the surfaces it adheres to. That part of each pleura, which extends from the sternum to the spine, constitutes the septum or mediastinum of the chest, between the two layers of which the heart is contained.

The substance of the heart is covered with a serous membrane termed the pericardium, which is reflected from the great vessels to form the sac, in which the heart plays. The reflected portion coheres firmly with the centrum tendinosum of the diaphragm, upon which the heart rests: it has great strength, and is divisible into a thin internal layer, the true continuation of the pericardium covering the heart, and a thick outer adventitious membrane. Dr. Baillie met with a case, in which the pericardium was deficient, and the heart invested by the pleuræ. The heart is fixed by its base, from whence the vena cava inferior descends through the diaphragm, —the vena cava superior and aorta ascend towards the neck, where their branches are distributed,—and the pulmonary artery and veins extend transversely outwards into either lung.

The form and dimensions of each lung, while the chest is entire, are determined by the atmospheric pressure. *A lung is laid out in cells, into which the windpipe opens.* The windpipe or trachea, continuous through the larynx with the fauces, is a tube nearly cylindrical, and about ten lines in diameter, consisting of from fifteen to twenty incomplete rings of cartilage, the deficiency of which at the back part is made up by transverse muscular fibres, and by an elastic membrane, which serves at the same time to connect each ring with those adjoining it. The tube is lined by a vascular and sensible membrane, continued from the lining membrane of the fauces, and termed a mucous membrane from the nature of its secretion. The trachea descends from the throat into the chest, and opposite to the third dorsal vertebra divides into two smaller tubes termed bronchi: of these the right is the shortest and most capacious; for the right lung is larger than the left, the greater part of the heart being placed upon the left side. The left lung is divided into two lobes, the right lung into three, by fissures extending to the root of each. The bronchus divides into a branch for each lobe; and in the substance of the lung, these branches, after a few subdivisions, lose all trace of the imperfect cartilaginous rings which belong to the first parts of the respiratory tube, and become membranous. The branching air-tubes terminate in minute cells at every point in the lung, each lobe of which is subdivided into innumerable lobules.

The cells of the lungs, while the chest is entire, are always distended beyond their natural limits. The substance of the lung is elastic, but its resistance is of no effect against the disproportionate pressure of the atmosphere. If at an intercostal space the skin, muscles, and pleura reflexa be cut through, atmospheric air enters the chest through the aperture, the lung recedes from the ribs and shrinks to a smaller dimension. By this well-known experiment the atmospheric pressure is equalized upon either surface of the lung, and the organ takes a volume determined by its elasticity and weight. Dr. Carson ingeniously contrived to measure the resistance of the lungs in the contracted state of the chest to the atmospheric pressure, by observing the height to which a column of water must be raised in order to force air into the lungs, after the opening of the intercostal spaces, in sufficient volume to fill the cavity of the chest as before. He employed a hollow glass globe, to one side of which a tube was let in, that admitted of being securely fastened into the trachea of a slaughtered animal; to the other was attached a vertical tube bent near its junction with the globe, into which water was poured, after openings had been made between the ribs. Through the means of this apparatus Dr. Carson ascertained that in calves, sheep, and large dogs, the resilience of the lungs is balanced by a column of water varying in height from one foot to a foot and a half; and in rabbits and cats, by a column of water varying in height from six to ten inches[a].

If the lungs were inelastic, but admitted of being unfolded to an indefinite extent on the enlargement of the chest, the pressure of the atmosphere upon the inner surface of the chest would be the same as elsewhere; but it is clear that in proportion as the lungs have a tendency to resist the atmospheric pressure, or in other words to recede from the pleura reflexa, the weight of the atmosphere must be lessened upon all the parts against which the lungs are applied. Thus it happens that the outer surface of the heart is not at any time exposed to the same degree of pressure with parts external to the chest; and that the degree of pressure is yet further reduced, when upon the dilatation of the chest the lungs become further expanded, and their elastic resiliency increased.

The heart is of a conical figure: the septum, which divides its cavities, is disposed nearly in its long axis, but gives the apex of the heart to the left ventricle exclusively. The shape of each chamber of the right cavity is triangular, of the left oval: the contents of each are about two ounces. The auricles are of a thin substance; the ventricles are of considerable thickness; the muscular fibres of the right auricle are disposed in parallel lacerti, prominent inwards, called musculi pectinati: a like appearance is not seen in the left auricle. In the appendage of each auricle the lacerti are reticularly interwoven. The external layer of muscular fibres in the left ventricle, extends spirally from the base and superior longitudinal furrow forwards and towards the left, and turning round the margin of the heart reaches the longitudinal furrow upon its under surface. The external layer of muscular fibres upon the right ventricle, extends in a like manner from the base and inferior longitudinal furrow obliquely forwards to the superior. In the middle layer no regular disposition seems observed. The lacerti of the inner layer again intersect each other reticularly, without any exact order, except that in the left ventricle two fleshy columns, and in the right three or four, project towards the auricle. The aperture of either ventricle towards the artery, which rises from it, is perfectly smooth.

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[a] Phil. Trans. vol. cx. p. 42.

Either cavity of the heart is lined with a thin transparent membrane, which is readily separable from the inner surface of the auricles and ventricles, and is found to be continued along the artery, which terminates the latter, and along the veins that open into the former. This membrane is in a degree firmer and more opake upon the left side of the heart than upon the right. In the arteries it appears of a more brittle texture than in the veins: it is every where in contact with the blood, and is usually classed among the serous membranes.

At the opening of the inferior cava into the right auricle, the inner membrane is raised along the left margin of the vein, so as to form a crescentic fold, which is termed the Eustachian valve. By this provision, useful only in the fœtal state, the inferior cava is made to open exactly opposite to the fossa ovalis. Muscular fibres are often contained in the Eustachian valve. At the opening of the coronary vein, another semilunar fold of membrane forms a valve to guard its oblique aperture, and to prevent the regurgitation of blood from the auricle into the vein. No valve is placed upon the entrance of the superior cava into the right auricle, or of the pulmonary veins into the left.

The valve between each auricle and ventricle is a reduplicature of the inner membrane, thickened by intervening fibrous substance. Its floating margin is irregular, and presents three points in the right, two in the left ventricle; whence the former is termed the tricuspid, the latter the mitral valve. The floating edge of the valve is attached by short tendinous threads, called chordæ tendineæ, to the fleshy columns of the ventricle. In general each columna carnea receives all the tendinous chords from the opposite edges of two adjoining points of the valve. The valve at its points is about nine or ten lines in depth, intermediately about five. By the action of the fleshy columns the floating margin of the valve can be drawn together, and the passage closed from the ventricle into the auricle. The margin of the valve is thickened with numerous little granular bodies, called corpora sesamoïdea.

The valves at the root of the aorta and of the pulmonary artery are of a different description; they consist of three semilunar folds of the inner membrane attached by their circular margin, each along a third of the circumference of the artery. They are so disposed that when blood issues from the ventricle, they are thrown up, and lie in contact with the parietes of the artery: but upon the reflux of the blood towards the heart, they are thrown down and sacculated, while their floating margins, the centre of each of which is strengthened by a corpus sesamoïdeum, meet as tense chords, describing three radii of the circular aperture of the vessel. These valves are termed the sigmoïdal or semilunar valves of the aorta and pulmonary artery.

The heart is supplied with blood from the two coronary arteries, which are the first branches of the aorta; it has a large supply of lymphatic vessels, its nerves are derived from the sympathetics and nervi vagi.

An artery is a cylindrical and highly elastic tube; its thick texture is separable into, 1. An inner serous coat; 2. A middle fibrous coat, of a yellow colour in the larger trunks, of a reddish brown in the smaller branches, composed of fibres, which are disposed transversely, but seem in some degree interwoven; they are very elastic, and at the same time so brittle, that the pressure of a ligature tied upon an artery cuts through the fibrous together with the inner coat; and 3. An outer cellular coat, consisting of tough white elastic fibres closely interwoven, which the pressure of a ligature does not divide. Dr. Hales ascertained that the force required for bursting one of the carotids of a dog, is equal to that of a column of water one hundred and ninety feet high. He does not remark that the artery became dilated, but observes that with this force the artery burst at once.

A vein is a flexible tube of great strength, but of little elasticity, separable into an inner serous tunic, and a dense external coat of white and closely interwoven fibres. The inner coat is thrown at intervals into semilunar folds that occur in pairs, and are attached by their convex margins each to half the circumference of a vein: as the blood flows towards the heart, these valves lie against the sides of the vessel; upon its reflux they are thrown down and their edges meet. Valves are not found in the venæ cavæ or in the visceral veins: they are found in the iliac veins, in the veins of the neck and head, and of the extremities, especially in those which are subcutaneous. Dr. Hales found the jugular vein of a mare to burst with a force equal to that of a column of water one hundred and forty-four feet high[b].

When an artery divides, the two branches have a common area larger than that of the trunk, and in most instances diverge at an acute angle; the same is observed of veins. The arterial and venous trunks generally are distributed together: the largest arteries have one accompanying vein, the smaller arteries two. In the neck and extremities a superficial set of veins is added to that which accompanies the arteries. The area of the venous system is greater than that of the arterial, in the proportion of four to one, according to Borelli. The ratio between the capacity of individual arteries and veins in different parts, is very various: between the carotid and internal jugular 196:441, between the subclavian artery and vein 81:196, between the crural artery and vein 3844:7396, between the aorta and vena cava 9:16, between the splenic artery and vein 156:676[c].

Arteries and veins have their vasa vasorum, and are supplied with nerves derived from the sympathetic and from the spinal nerves, if not indiscriminately from all but the first, second, and portio mollis of the seventh.

If the chest and pericardium be laid open in an animal immediately after death, the heart is seen to continue beating, the action of the auricles and ventricles to alternate, the two auricles to be simultaneously relaxed at one moment, the two ventricles at the next. The passive state of each chamber of the heart is termed its diastole, the contrary state its systole.

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[b] Hæmastatics, p. 151.

[c] Haller. Elementa Physiologiæ, vol. i. p. 131.

During the systole of the ventricles, blood expelled from their cavities and thrown into the arteries urges on that before contained in either arterial trunk, and in its branches, in the capillary vessels, and in the veins, towards the auricles of the opposite side of the heart. During the succeeding diastole many forces continue to operate, which tend to diminish the area of the vascular system: and as the blood is prevented returning into the ventricles by the semilunar valves, they serve to propel it towards the auricles. These forces consist in the elasticity of the arteries themselves, in the compression of surrounding elastic organs, in the contraction of muscular parts, in the pressure of the atmosphere.

Various causes combine to give effect to these forces in filling the auricles with blood, which operate by taking off or diminishing the atmospheric pressure upon their outer surface. The auricle during its diastole spontaneously expands; the elasticity of the lungs constantly tends to draw asunder the walls of the auricle; and at the time of each inspiration, while the area of the chest is enlarging, the heart is probably relieved of external atmospheric pressure in the same manner as the lungs, although in a less degree.

The spontaneous expansion of the auricles is perhaps of no great effect; but of the three causes assigned to facilitate the entrance of the blood into their cavities, this is apparently the only one in operation during the fœtal state, or when the circulation is kept up, after laying open the chest, by means of an artificial respiration.

The extent to which the elastic resilience of the lungs contributes to diminish the atmospheric pressure upon the outer surface of the auricles, is shown by the experiments of Dr. Carson, which have been already detailed; but its effects are perhaps more strikingly illustrated by subsequent researches of the same author. It has always excited surprise that the arteries are comparatively empty after death, and that the blood accumulates exclusively in the veins and in the heart. In expectation of elucidating this phenomenon, Dr. Carson *killed a dog* by opening both sides of the chest. The body when subsequently examined, seemed every where unusually turgid with blood, the membranes appeared as if injected, the muscles bled when divided, and there were coagula of blood in the arteries[d]. But these uncommon appearances were produced by equalizing before the circulation ceased, the atmospheric pressure upon the mucous and serous surfaces of the lungs; or in other words, by preventing the suction which the resilience of the lungs usually produces after death, and which this experiment proves to be a cause sufficient to account for the empty state of arteries observed on dissection.

The effect of the dilatation of the thorax on the circulation of the blood, has been recently placed in a strong light by the experiments of Dr. Barry. One of these experiments consisted in tying the jugular vein of a horse, and inserting into the vein on the side open towards the heart, a flexible tube communicating with a spiral tube of glass, which stood in a vessel of coloured water. Each time that the animal inspired the fluid was seen to ascend in the spiral tube[e]. But it remains problematical whether this phenomenon be independent of the resilience of the lungs. For if we admit, that were the trachea closed and the chest to be dilated, the atmospheric pressure being taken off the heart, and operating without resistance upon the veins of other parts, would drive their contents towards the right auricle; yet in natural breathing the trachea is open, and permits the air to occupy the cells of the lungs, as promptly as the chest enlarges; so promptly, perhaps, as but for the resilience of the lungs to keep up a pressure upon the outer surface of the heart, equal to that which the air exerts through the column of blood in the veins upon its inner surface.

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[d] Medico-Chirurgical Trans. vol. xi. p. 165.

The question might be set at rest in the following way. Suppose that in an animal prepared for the preceding experiment, a closed tube were let into either pleura calculated to allow of the entrance of air as readily into the serous cavity, as it naturally passes into the bronchi, and that a stop-cock were fastened into the trachea. Upon closing the trachea by turning the stop-cock, and opening the tubes let into the pleuræ, the animal would continue for a time to move the chest as in breathing, and the coloured fluid would or would not rise in the spiral tube connected with the jugular vein at each effort at inspiration. If the fluid should remain at rest, its rise in the former experiment would be shown to result from the resilience of the lungs: if it should rise in the spiral tube, Dr. Barry's explanation of the phenomenon would prove to be correct.

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[e] Récherches Experimentales par D. Barry, M.D. p. 19.

But in whatever way it operate, certain it is that the influence of the state of the thorax upon the circulation is felt at every part of the system. During expiration, or in other words when the area of the thorax is diminished, the course of the blood is seen to be retarded in the superficial veins of the neck: the brain, if an opening has been made in the cranium, is observed to be lifted up; blood flows in a stronger gush from a divided artery, and even from a vein that, after having been tied, is punctured on the side remote from the heart[f].

The auricles, being thus filled with blood through the influence of various causes, contract: the area of each being diminished, the blood is partly thrown back upon the veins, and by its reflux from the right auricle produces a pulse sometimes visible in the internal jugular veins of thin persons,—in part enters the ventricle, which spontaneously dilates to receive it.

The auricles then become relaxed, and the ventricles act, and drive back upon the auricles the blood situated behind their valves, the tricuspid or the mitral: and it is worthy of remark, how completely the elements of the blood must become blended together, as the stream first rushes into each auricle, then is in part thrown back into the veins, is again carried into the auricle, and then thrown upon the ventricle; is again in part thrown back into the auricle, and at last reaching the interior of the ventricle and driven along all the irregular channels and hollows of its surface, is eventually propelled into the artery.

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[f] Majendie. Elémens de Physiologie, tome ii. p. 423.

At the moment when the ventricles act, the apex of the heart is thrown forwards against the side of the chest. Various solutions have been proposed of this phenomenon; of which the most ingenious attributes it to the extension of the curve of the aorta upon the rush of blood from the left ventricle. But it is questionable whether the cause supposed would produce the effect which it is employed to explain; and it is certain that when its influence is wholly removed, the movement of the apex of the heart may take place as before. If the heart of a dog recently killed, while yet palpitating, be placed upon a table, the apex is observed to be lifted up at each contraction of the empty ventricles. In this instance it is obvious that the movement of the apex of the heart must either depend upon the direct action of the exterior fibres of the ventricle, which tend when the base of the heart is fixed (as on this occasion by its weight alone) to raise the apex, or be indirectly produced through the reaction of the surface, upon which the heart rests when contracting.

The force, with which the different chambers of the heart contract, is not easily computed. But the capital experiments of Hales throw considerable light upon this question, and furnish an approximation to the average pressure upon the blood during the systole of the left ventricle. In some of the experiments of Dr. Hales, tubes were inserted into the arteries of living animals, and the height observed to which the blood ascended in them. In a glass tube a sixth of an inch in diameter fixed into the crural artery of a mare, the blood rose eight feet three inches above the level of the left ventricle of the heart; but it did not attain its full height at once: it rushed up about half way in an instant, and afterwards gradually at each pulse, twelve, eight, six, four, two, and sometimes one inch: when it was at its full height, it would rise and fall at and after each pulse two, three, or four inches, and sometimes it would fall twelve or fourteen inches, and have there for a time the same vibrations up and down, at and after each pulse, as it had when it was at its full height, to which it would rise again after forty or fifty pulses. When the glass tube was taken away, the greatest height of the jet of blood was not above two feet. Horses were found to expire when after continued hemorrhage the blood stood only at two feet in the tube. Upon a measurement of the area of the left ventricle, and comparing it with the height at which the blood stood in the tube in the preceding experiment, Dr. Hales concludes that the pressure of the blood, which the left ventricle of the horse sustains at the instant, when it is going to exert a contractile force sufficient to propel it with considerable force into the aorta, is 113.22 pounds.

"If we suppose," observes Dr. Hales, "that the blood would rise 7½ feet high in a tube fixed to the carotid artery of a man, and that the internal area of the left ventricle of the heart is equal to fifteen square inches, these multiplied into 7½ feet, give 1350 cubic inches of blood, which press upon that ventricle when first it begins to contract, a weight equal to 51.5 pounds".[g]

The alternate action and relaxation of the muscular fibres of the heart appear not, like similar phenomena in the diaphragm, to depend upon a series of impressions transmitted from the brain or spinal chord. If the heart be taken from the body of an animal immediately after death,—if the blood be carefully washed from its internal surface,—if at the transverse furrow the auricles be separated from the ventricles by a clean incision, the alternate states of action and relaxation continue to succeed each other in each part as before. For the brief period, during which it is reasonable to suppose that the heart retains its perfect organization, no stimulus seems required to excite it to contract. The alternation of action and repose seems natural to it, or to be the result of its structure.

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[g] Hæmastatics, p. 21 and 39.

It is remarkable that if the heart yet beating be placed in warm water, it continues to act more briskly and for a longer time than if exposed to the air; but that if water be injected into its blood vessels, its flesh becomes pale and swollen, and after two or three beats hardens permanently; and that if its fibres be transversely cut through, their action is stopped at once.

In the former instance the heart is placed under circumstances, which partially correspond with its state in the living body. With a little contrivance every influence to which it is habituated during life, excepting that of the nervous system, may for a short space after death, be kept up upon the heart. The researches of Mr. Brodie have successfully elucidated the phenomena which ensue upon sustaining in dead animals an artificial respiration, extending to some very curious results presently to be noticed, respecting secretion and the source of animal heat, the original experiment of Vesalius and of Hooke. If the chest be alternately inflated with and emptied of atmospheric air, the blood which passes through the lungs regains a florid hue, the heart's action does not sink as when black blood is contained in both its cavities; and a complete circulation of the blood may be preserved for the period of two hours and a half after death[h]. Under other circumstances the heart's action flags, and ceases in from five to ten minutes after apparent death. The preceding phenomena were observed when the head had been removed after tying the vessels in the neck. Dr. Wilson Philip found that in warm-blooded animals the circulation might be kept up after death by means of artificial respiration equally well, whether the brain and spinal chord had been left or removed; and that in frogs it spontaneously continues for a considerable period after the same degree of mutilation[i]. Molæ, it is said, are occasionally developed in the uterus, which have neither brain nor spinal marrow, in which, nevertheless, a circulation has existed.

But while the fact appears thus established, that the heart does not need a specific irritation through the nerves to cause it to contract, it must not be lost sight of that the brain and spinal chord influence remarkably the frequency and vigour of its action. How promptly mental emotions affect the heart, is too familiarly known to need illustration. The effect of physical impressions upon the brain and spinal chord is not less decided. The experiments of Le Gallois, and the more discriminating researches of Dr. Wilson Philip, sufficiently prove this assertion. When spirit of wine was applied to the surface of the brain in a stunned rabbit, or to the cervical or dorsal part of the spinal chord, the heart was observed to beat more quickly than before: this effect gradually subsided, and the heart beat again as at first. When an infusion of opium was employed, the heart's action was found to be at first rendered stronger, then became enfeebled; but on washing off the poison the heart recovered itself. On crushing suddenly a large portion of the brain or spinal chord in a rabbit with a steel instrument, the heart's action was observed to be immediately enfeebled, if not stopped entirely. On crushing the brain of a frog, the heart was observed to perform a few quick and weak contractions; it then became quite still for about half a minute: after this its beating returned, at first imperfectly, but in ten minutes afterwards it was sufficiently restored to support the circulation, but with less force than before the destruction of the brain. The spinal chord was then crushed at one blow; the heart again beat quickly and feebly for a few seconds, and then seemed entirely to have lost its power of acting. Dr. Wilson Philip remarked that the heart's action in these experiments was rendered quicker or slower, stronger or more feeble, but never rendered irregular[k].

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[h] Phil. Trans. vol. ci. p. 39. [i] Experimental Inquiries, p. 75.

The heart of an adult appears to perform from seventy to seventy-five beats in a minute; in infants of two years of age, a hundred; at an earlier age the pulse is yet more frequent; at puberty about eighty; towards old age the heart acts at longer intervals, and the pulse does not exceed sixty in a minute.

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[k] Experimental Inquiries, p. 36.

The quantity of blood in the body of an adult is estimated on an average at from thirty to forty pounds: between one and two ounces are supposed to be propelled at each contraction of the left ventricle into the aorta, with a velocity of 120 feet in a minute; and as the contraction of the ventricle occupies a third only of the period from one systole to another, the mean velocity of the blood in the aorta may be computed at eight inches in a second[l].

The force, with which the blood is propelled, appears employed in overcoming the friction of the innumerable capillary tubes which it traverses. In the capacious venous trunks the blood moves slowly onwards in an equable stream, and with an impulse so moderate, as to rise in a vertical tube, according to the experiments of Hales upon the horse, to the height of six inches only. In the smallest arteries the flow of the blood *per saltum* appears to be lost,—a phenomenon which is included under the following general proposition in mechanics, that an intermittent motion may be changed into a continuous motion by employing the force, which produces it, to compress a spring, the reaction of which is constant[m].

From the preceding details, the motion of the blood would seem to be entirely derived from the action of the heart. But there are animals in which a circulation seems to take place that have no heart, and the mola, or imperfect human fœtus, sometimes attains considerable maturity with a circulation carried on by arteries and veins alone. Mr. Brodie examined a fœtus of this description, born as usual a twin; it had grown to the height of thirteen inches; and although many organs were deficient or malformed, yet the brain and spinal chord appeared to be complete; the principal parts of the abdominal viscera were found, and the body had nearly the natural form. The umbilical chord contained a vein with a single artery, the structure of which seems to have presented nothing unusual. The vein opened into the vena cava, from which branches passed to every part of the body: the artery opened into the left internal iliac, from which was derived an aorta, having no arch at its upper part, but terminating in branches to the head and arms. No communication existed between the trunks of the arterial and venous systems, and we must suppose that the blood was returned from the placenta along the artery, was distributed through its branches to every part of the body, was conveyed back by the veins of the body to the umbilical vein, and thence to the placenta again[n].

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[l] Young's Medical Literature, p. 609.

[m] Majendie. Elémens de Physiologie, tome ii. p. 388.

In this and similar cases, it is presumed that motion, limited to one direction by the valves in the venous system, is given to the blood by the contraction of the arteries and of the capillary vessels. Upon a like supposition the fact has been explained, that after the removal of the heart if transparent parts of the body be examined in a microscope, the blood is seen to flow for a time in the minute vessels. But little is known of the nature of the capillaries: their existence is only a matter of inference; the globules of the blood are seen traversing the web of the frog's foot in single files, and are supposed to move in tubes of a similar nature to the arteries. These channels are capable of enlarging, and of admitting more blood at one time than at another. If an irritant, as diluted liquor ammoniæ, be applied to the web of the frog's foot, the surface becomes for a few seconds lighter and more transparent, as if through the contraction of its vessels: presently after, the small vessels become dilated, the blood flows more slowly through them, and here and there its course is entirely arrested: bathed with cold water, the part slowly recovers itself, and the vessels contract. A particle of dust resting within the eyelids, produces in a few seconds an appearance of a fine vascular network upon the white part of the eye; it is supposed that this results from the sudden enlargement of vessels, which were before too minute to be coloured. But more is known by direct observation of the properties of the larger arteries, and the phenomena of the capillary circulation are only to be explained by reasoning upon analogy.

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[n] Phil. Trans. vol. xcix. p. 163.

The first phenomenon which attracts attention in the larger arteries of the body, is their sensible pulsation; it is synchronous with the action of the left ventricle, and results from the rush of blood into the aorta. The velocity of a pulsation, according to Dr. Young, is sixteen feet in a second[o]; and consistently with this estimate, the throb of the arteries appears to be simultaneous in every part.

In a curved artery, as for instance in the temporal, the pulse is visible; the artery, if not elongated at each systole of the left ventricle, is moved from its place, to which it returns during the succeeding diastole. But if a straight artery be examined, as for instance the common carotid when exposed in the neck of an ass, no motion whatever or change of figure is distinguishable, as long as the animal remains free from alarm or suffering. And in order to perceive the pulse, it is necessary, as Dr. Parry observed, to indent with the finger the artery, so as to oppose it to the rush of blood.

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[o] Young's Medical Literature, p. 605.

M. Majendie mentions that the aorta is visibly dilated at each systole of the left ventricle, and that the same change may be shown in the crural artery by the following experiment. If a ligature be passed behind the crural artery and vein round the thigh of a dog, and drawn tight, so that the circulation be sustained through the two crural vessels alone, upon compressing the artery between the finger and thumb, it gradually contracts on the side remote from the heart; but upon removing the finger and thumb, the artery quickly becomes again distended with blood, and at each pulse is visibly dilated.

The preceding appearances in arteries, admit perhaps of being referred to the acknowledged elasticity of their textures. But on other occasions partial changes are observed in the calibre of arteries, while the pressure of the circulation is equal upon every part which seem to result from another principle, which can be produced by blind physiological experiments, or occur in the order of nature for definite and important objects.

Mr. Hunter observed that when a large artery, as for instance the crural artery of a dog, has been exposed for some time to the air, its diameter becomes gradually diminished. Dr. Parry observed further, that if a ligature be thrown round an exposed artery so as merely to lie in contact with its surface without the knot being drawn, the vessel contracts where the foreign body touches it, but preserves an equal area upon either side of the ligature. When a portion of an artery is removed from a living animal, it slowly contracts during the first minute or two to less than half its first diameter. If a large artery in the living body, as for instance the carotid in an ass, or the crural artery of a dog, be rubbed for half a minute between the finger and thumb, its diameter at the part so treated becomes half as large again. Upon cutting out a portion containing the dilated part, the whole contracts pretty equably; and on slitting it longitudinally, the pressure appears to have produced no ecchymosis in, or injury to, the internal coats of the vessel.

Hemorrhage from a small artery, that has been divided, becomes slackened in a short time; and before it can be supposed that faintness, a languor of the circulation, and the coagulation of blood around and in the orifice of the vessel, can have taken place. The spontaneous stopping of arterial hemorrhage seems to occur more readily in animals than in human beings. If in an experiment upon a horse or ass a muscular artery of the size of a crow-quill be divided, and the subsequent changes watched, the jet of blood is seen to diminish gradually in volume, and the distance to which it is projected becomes less and less; at length the blood merely trickles over the adjoining surface, then but slightly oozes, then stops. The first changes in this series obviously result from the contraction of the extremity of the divided artery. Cold, which has so remarkable an effect in producing contraction of the skin, accelerates the contraction of an artery. Warmth and moisture, which relax the skin, encourage the continuance of hemorrhage.

When the main artery is tied in a part, the blood finds its way more freely than before through collateral vessels, the branches of which anastomose. If the facts which have been previously stated are sufficient to show that arteries in warm-blooded animals are ordinarily irritable parts, it is easy to account for the prompt enlargement of the anastomosing vessels in the present instance. We have but to suppose that the usual resistance of the vessels to the flow of blood is diminished by a relaxation of their tunics, the final cause of which is as obvious as the physical cause which determines it is obscure.

On some occasions blood is found in particular parts in larger quantity than usual. Upon examining the uterus and ovaria in a rabbit killed when at heat, Mr. Cruikshank found these organs turgid and black with blood; when injected with size and vermilion, they were rendered much redder than usual. The capillary vessels had become enlarged, and admitted more of the coloured particles than before. The flushing of the countenance is probably produced in the same way with the local determination of blood in the preceding instance. The simplest explanation of both cases is to suppose the vessels irritable parts, that are relaxed, when a larger draught of blood is required at any part. The hypothesis of a sudden constriction at any part of the capillary system, as the cause of the dilatation of the vessels on the side next the ventricle, may be considered untenable, since it is opposed to analogy. If a large artery be tied, it does not become more capacious on the side next the heart.

The opinion, that the flow of blood in increased quantity to a part results from the relaxation of its small arteries, is remarkably confirmed by what is noticed respecting the larger vessels, wherever local action frequently occurs, or happens to exist for a considerable period. The arteries of such parts become elongated and tortuous. This is the character of the arteries of the testis, of the uterus, of the mammæ towards the latter period of and after uterogestation, of the face and temples. The latter instance, perhaps, requires an explanation to show its coincidence with the three former. In a child the temporal arteries are straight; in proportion as life advances they become more and more tortuous; but as life has advanced, the sources of passion and excitement have multiplied, and the face has flushed and burnt, and the temples have throbbed with an increased flow of blood on countless occasions. It remains to show in what manner the tortuous form of arteries is consistent with the explanation of local action which I have advanced.

We may presume that an artery at the average tone of arteries would be affected in the same manner by an unusually forcible contraction of the left ventricle, as a relaxed artery under the ordinary pressure of the blood. The former case is easily obtained. It has been already mentioned that the carotid artery laid bare in the neck of an ass lies without apparent change, when the animal becomes composed. But if the animal be alarmed, as by holding its nostrils for a few seconds, the heart acts violently, and the carotid artery leaps from its place and becomes elongated and tortuous at each stroke of the ventricle. It follows that if the coats of the same vessel were specially relaxed, a like phenomenon would ensue during the ordinary action of the heart. But if an artery were frequently lengthened and rendered tortuous, it is analogically certain that it would grow to this shape, and become permanently of the figure thus accidentally given to it.

It appears, therefore, that the phenomena of local action whether in large or in small arteries are equally referable to one cause, the spontaneous relaxation of the coats of these vessels. But where local action exists, the veins likewise become tortuous. Let us inquire whether this circumstance may result from the same cause.

It is not likely that veins are irritable; the effect of their valves, which act by their mechanical adjustment to a given area, would be defeated were this area readily capable of enlargement.

What are termed varicose veins are tortuous and dilated veins. They are frequently observed below the integuments of the thigh and leg. No doubt is entertained that the veins of the leg often become varicose through the pressure of the column of blood in the descending cava, which by a gradual process of dilatation renders each pair of valves in succession useless. The same pressure, which gradually dilates the veins, naturally tends to elongate them. Pressure, then, upon the inner surface of a vein, tends to enlarge and elongate it.

Varicose veins of the legs are again produced by ligatures tied below the knee; the superficial veins are in this instance observed to be continually swollen, and gradually to become tortuous as if knotted. The swollen state of the veins shows the internal pressure to which they are subjected: but this internal pressure is the force of the blood propelled from the left ventricle.

Now by our hypothesis, the blood during local action would arrive in the veins through larger channels than before; its force therefore would be less broken; its pressure would be increased upon the veins. But increased pressure upon the inner surface of the veins has just been shown to enlarge and elongate them; and thus the state of the veins in parts subject to local action tends to support the theory which I have advanced.

Blood is not returned to the heart so readily from a dependent part, as from parts whence it has to descend. The circulation in the lower extremities always appears more sluggish than in the upper part of the body. If the hand be held up, it becomes whiter and less in bulk; if it hang down, it becomes swollen and darker. In the one case the weight of the blood favours its return by the veins to the heart; in the other case its weight is opposed to its ascent along the veins. The veins of the lower extremities have coats as thick as those of arteries: the arteries are perfectly straight, in order that there may be no unnecessary waste of the impulse derived from the heart.

The arteries distributed to the human brain are four in number, the two internal carotids and the two vertebrals. The brain is an organ of so slight and delicate a texture, as to suffer more readily than any other from an unusual force of the blood in the arteries, or from its accumulation in the veins. Accordingly in some animals, as for instance in the common ox, the carotid artery, upon entering the skull, divides into many branches, which subsequently re-unite and form a trunk, in which the force of the blood must be greatly diminished. This contrivance is termed the rete mirabile. In human beings another provision is employed: each of the four arteries of the brain is bent twice at an abrupt curve just before or after entering the cranium. As less pressure is necessarily made upon the vessels beyond these curves, the arteries of the brain are formed consistently with the œconomy of Nature of much thinner coats than arteries of the same size elsewhere.

The veins of the brain, instead of collecting into large trunks continually varying in their degree of distension, open into cylindrical or triangular canals in the dura mater, which are termed sinuses, and terminate after circuitous routes in the internal jugular vein of either side. The sinuses of the dura mater are formed of materials so dense and so strictly adherent to the cranial bones, that they can at no time materially alter in dimension. The oblique entrance of the veins of the brain into the sinuses, the undilatable nature of the latter, their long and winding course, tend greatly to prevent the reflux of venous blood upon the brain, when its entrance into the chest is impeded.

CHAPTER V.

OF THE PULMONARY CIRCULATION.

THE blood probably suffers some alteration at every instant in every part of the vascular system; but the principal changes which it undergoes appear to take place in the capillary vessels. The heart and arteries and veins are machinery for propelling the blood to every organ, but in the capillaries the ends of the circulation appear to be attained.

In the human body there essentially exist two sets of capillary vessels, the one interposed between the pulmonary artery and the pulmonary veins, the other between the branches of the aorta, and the veins which return blood to the right side of the heart.

Each lung is a tissue of air-cells, with which the windpipe communicates in a manner already described, and upon which the capillaries of the pulmonary artery ramify.

If a lung be inflated and dried, its substance upon a section independently of the arteries and veins cut through appears uniformly porous. The larger pores appear sections of tubes, the lesser are shallow cups, being segments of air-cells. The air-cells are smaller, as M. Majendie observed, in infants than in adults, in adults than in persons advanced in age. In the lungs from a subject about five years of age, I found the air-cells vary in size, but on an average to be $\frac{1}{100}$ of an inch in diameter, and to be nearly circular. In the lungs from a subject about fifty years of age, their form seemed not to be as regular or uniform as in the preceding instance: their size varied from $\frac{1}{30}$ to $\frac{1}{70}$ of an inch. The extent of the internal surface of the lung is relatively less in proportion as the air-cells are larger and less numerous.

The pulmonary artery divides into a branch to each lung, which subdivides into branches for each lobe, and for each lobule of a lung. These vessels are accompanied by similar ramifications of the pulmonary veins. In the root of each lung the artery with the veins before and below it extends transversely outwards. The bronchus descends obliquely behind the blood vessels. If coloured water be thrown into the pulmonary artery, it passes into the pulmonary veins, and in part escapes into the bronchi. In the lung of the turtle the air-cells are remarkably large and irregular in their figure; and after a successful injection their surface is found to be reddened with capillary vessels containing size and vermilion. In the lung of a frog the course of the blood in single files from the arteries into the veins may be seen with a microscope. The flow of the blood through the lungs may be considered easier than in any other part of the body, in as far as the atmospheric pressure upon the vessels is counteracted to a trifling degree by the resilience of the texture of the lung.

Each lung receives two or three vessels from the aorta termed bronchial arteries, which are distributed with the bronchi. The pulmonary nerves are derived from the nervi vagi, which pass behind the root of each lung, and throw a plexus of branches round it: their final distribution has not been traced. The lymphatic vessels from the substance and superficies of the lungs are received into a vast number of conglobate glands disposed around the bronchi and the bifurcation of the trachea. They are remarkable for their black colour, which increases with age. The lung itself, of a pink colour in infancy, gradually becomes mottled with black. The dark hue in each case is supposed to result from carbon disengaged in the substance of the lungs.

Through the windpipe atmospheric air finds its way into the cells of the lungs: it is inhaled at the instant after birth, and is continually changed and replaced by fresh draughts through the operation of muscles, which alternately expand and contract the cavity of the chest as long as life remains. If the lungs were inextensible and of a sufficiently firm texture, and the muscles which enlarge the chest were to act with unlimited force, a vacuum would be formed between the pleura pulmonalis and the pleura reflexa at each attempt to inspire, and no air would enter the lungs. But as the lungs are readily extensible, atmospheric air rushes into and dilates their cells in exact proportion to the expansion of the area of the chest, and holds the two surfaces of the serous membrane in strict contact:—yet the same points are not always in apposition: when the chest enlarges, the surface of the lung during its expansion slides upon the pleura reflexa, as is shown by the elongation of the shreds of lymph by which the two layers of pleura are often found joined together after inflammation.

The passage of air into the lungs is so free, that the muscles which dilate the chest are not opposed by the atmospheric pressure in a greater degree than those which move the limbs; but they have to overcome the resilience of the lungs, the elasticity of the abdominal parietes, and the resistance of the joints of the ribs, which all favour the state of expiration.

The term breathing or respiration includes both the mechanical operation of renewing the air within the lungs, and the changes to which its presence there contributes.

The mechanism, by which the chest admits of being alternately enlarged and diminished, has already been described: every provision which it contains is employed in a greater or less degree at every repetition of breathing. The difference between a moderate and a deep inspiration is in the extent only, to which the diaphragm and the muscles that elevate the ribs contract. But it may be observed, that for the fullest enlargement of the chest, the scapula and clavicle are raised and carried backward by the trapezius, levator scapulæ, and rhomboïd muscles, so as to give greater effect to the action of the serratus magnus and pectoralis minor; and that to yield a freer passage to the air, the nostrils are dilated, the larynx descends, and the rima glottidis is enlarged. During each expiration the rima glottidis is narrowed. Ordinary breathing takes place between the limits of forced inspiration on the one hand, and forced expiration on the other.

Numerous experiments have been made to ascertain the quantity of air alternately drawn into and thrown out of the chest, in ordinary breathing. Those of Dr. Menzies, which coincide nearly in their result with the researches of Jurin and Fontana, are commonly esteemed deserving of credit; but they differ remarkably from the observations of Sir H. Davy and of Messrs. Allen and Pepys. Differences in the relative size of the thorax in different persons, a difference in the frequency with which breathing is performed, and perhaps other causes may have combined to produce this discrepancy. The frequency of respiration ranges between fourteen and twenty-seven times in a minute, but appears commonly to be from seventeen to twenty.

Dr. Menzies employed two processes in estimating the quantity of air habitually inspired. A healthy man five feet eight inches in height, and somewhat more than three feet about the chest, stood immersed in warm water to above his breast, in a vessel which narrowing at the upper part allowed of an accurate estimate of the level to which the water alternately rose and fell while he breathed. His pulse both before and after immersion beat sixty-four or sixty-five, and his respirations were fourteen or fourteen and a half in the space of a minute; and they continued the same during the two hours and upwards that he remained in the vessel without suffering inconvenience. The quantity of air thrown out at each expiration averaged at 46.76 cubic inches. The same person afterwards was employed to fill a cow's allantoïd, a membranous sac well calculated for such a purpose, by repeated expirations. The allantoïd was found to contain 2700 cubic inches of air, and was filled in many trials with fifty-eight expirations, which gives 46.55 cubic inches as the quantity of air expired each time. The same trials repeated upon a man five feet and an inch in height, whose pulse beat seventy-two, and the number of whose respirations was eighteen in a minute, gave from thirty-eight to forty cubic inches as the measure of a common expiration. Repeating the experiment himself, Dr. Menzies filled an allantoïd containing

2400 cubic inches by about fifty-six expirations, giving 42.8 cubic inches as the average quantity of each; and found that he exhausted the allantoïd, when previously filled with atmospheric air, by an equal number of inspirations[a]. Sir H. Davy estimates the quantity of a single inspiration at thirteen or seventeen cubic inches; Messrs. Allen and Pepys at sixteen and a half; Mr. Kite at seventeen; Mr. Abernethy at twelve.

Dr. Menzies observed that many individuals were capable by a forced expiration of throwing out an additional seventy cubic inches; and that the difference between an extreme inspiration and an extreme expiration often exceeded two hundred cubic inches. The lungs after death under ordinary circumstances are probably reduced to the same compass as by a forced expiration during life. Messrs. Allen and Pepys found that the lungs of a stout man about five feet eight inches high after death contained nearly one hundred cubic inches of air. Of this quantity 31.58 cubic inches were expelled by the resilience of the lungs upon opening the thorax[b].

Dr. Bostock estimates the quantity of air, which may be voluntarily expelled from the lungs after an ordinary expiration, at 160 or 170 cubic inches, from trials made upon himself and others. Adding to this quantity 120 cubic inches for the residual air in the lungs, he supposes 290 cubic inches to be the entire contents of the lungs in their natural state, to which about forty cubic inches more are added by an ordinary inspiration. According to this calculation, $\frac{1}{8}$ of the whole contents of the lungs is changed by each respiration[c].

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[a] Menzies on Respiration, p. 21 et seq.

[b] Phil. Trans. vol. xcix. p. 411.

Atmospheric air consists of seventy-nine parts of nitrogen and twenty-one of oxygen. A small proportion of both elements, which has been variously estimated[d], is found to have disappeared at each expiration: but this phenomenon loses interest when compared with the curious circumstance, that a disproportionate quantity of oxygen has disappeared, and has been nearly or completely replaced by carbonic acid. In the elaborate experiments of Messrs. Allen and Pepys, from 8 to 8.5 per cent of carbonic acid were observed to be produced by each respiration. When the breathing was more rapid than usual, a larger quantity of carbonic acid was emitted in a given time, but the proportion at each expiration remained the same. The proportions of carbonic acid in the first and last portions emitted after a deep inspiration differed as widely as from 3.5 to 9.5 per cent. On an average it appeared that about 27.5 cubic inches of carbonic acid are produced per minute, or 39534 in twenty-four hours; a quantity which contains about eleven ounces troy of solid carbon[e].

If a series of experiments conducted with great skill and caution, and leading to a theory the most simple, were sufficient to determine a question in physiology, the researches of Messrs. Allen and Pepys would set at rest every doubt respecting the changes produced in the air and upon the blood in breathing. They tend to establish the fact, that in respiration the nitrogen of atmospheric air remains unchanged, and that the carbonic acid produced exactly equals the volume of oxygen which disappears. But by former experiments Messrs. Allen and Pepys had ascertained, that in the formation of a volume of carbonic acid during combustion an equal volume of oxygen is consumed: and it is admitted that the change wrought upon the blood in the pulmonary circulation is apparently no more than might result from the abstraction of carbon. Thus the essential phenomena of respiration appear contained in, or consistent with, the simple expression, that the carbon of the blood unites in the lungs with the oxygen of the atmosphere to form carbonic acid.

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[c] Bostock's Elements of Physiology, vol. ii. p. 34.

[d] By Sir H. Davy at $\frac{1}{70}$ to $\frac{1}{100}$. Researches, &c. p. 431.

[e] Phil. Trans. vol. xcviii. p. 277.

Facts are not wanting to illustrate every step of the process. Plants as well as animals deteriorate atmospheric air by substituting carbonic acid for oxygen; and the experiments of M. Huber and of Mr. Ellis establish the fact, that when a plant growing in a closed vessel has consumed all the oxygen of the atmospheric air which it contained, the nitrogen, which remains undiminished in quantity, becomes carburetted; as if carbon spontaneously separated from the living body in a form fitted to combine with the elements of the atmosphere, and in the defect of oxygen might for a time continue to be eliminated and to unite with another principle.

But it is evident that the preceding theory rests upon the position that the carbonic acid produced in breathing exactly equals the volume of oxygen lost. Now although this position be supported by the able researches of Messrs. Allen and Pepys, and has been advocated by

Mr. Ellis, M. Majendie, and others, it cannot be admitted to be universally true.

In the experiments of Lavoisier and Seguin, the proportion of oxygen consumed exceeded that necessary for the production of carbonic acid in the ratio of about 100 to 81.5, a result which exactly coincides with the researches of Sir H. Davy. In the recent experiments of Dr. Edwards, in which small animals were immersed for a definite period in large quantities of air, the general fact of the surplus quantity of oxygen lost is abundantly proved: at the same time the apparently conflicting opinions of preceding physiologists are reconciled by the essential variableness of the results, which the experiments alluded to exhibit. Dr. Edwards's general conclusion is, that the excess of oxygen consumed in breathing above the volume of carbonic acid produced, varies from nearly one-third of the oxygen that disappears to almost nothing; that the variation depends upon the species of the animal employed, upon its age, or some peculiarity in its constitution; and also that it varies considerably in the same individual at different times[f].

Upon these grounds we must adopt a different theory of respiration. Part of the oxygen that disappears we must suppose to be absorbed in the lungs, and the rest may either combine with the carbon of the blood to form carbonic acid, or the whole may be absorbed, and the expired carbonic acid may be a new secretion. Dr. Edwards adopts the latter opinion, and supports it by the following curious facts. If frogs are confined during the month of March for the period of eight hours in pure hydrogen after the previous exhaustion of their lungs by pressure, they continue to breathe, although less and less vigorously, till near the close of the experiment, during which a volume of carbonic acid nearly equal to the bulk of the animal employed is given out. A similar result ensued in experiments upon kittens. The young of many species of warm-blooded animals can exist for some time after birth without the contact of air: after two or three minutes, voluntary motion ceases; but from time to time deep inspirations are drawn accompanied with yawnings and movements of the whole trunk. A kitten three or four days old was placed in a receiver containing pure hydrogen, and performed in nineteen minutes about as many inspirations. Upon examining the air in which the animal had been immersed, it was found to contain twelve times as much carbonic acid as could be accounted for by the residual air in the lungs at the beginning of the experiment[g].

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[f] De l'Influence des Agens Physiques, &c. p. 418. See likewise Dr. Bostock's able disquisition of this subject; Elements of Physiology, vol. ii. p. 97 & 110. He concludes that a man under ordinary circumstances consumes about 45000 cubic inches of oxygen, and produces about 40000 cubic inches of carbonic acid in the space of twenty-four hours.

But other circumstances, which Dr. Edwards mentions, seem to render the preceding facts inconclusive upon the question they are produced to illustrate. It seems by no means certain that the carbonic acid obtained in these experiments came from the lungs. If a frog during the summer months be immersed in hydrogen, it either ceases to breathe, or breathes very rarely: nevertheless carbonic acid is exhaled. Or supposing that the carbonic acid obtained in these experiments proceeded from the lungs, we still are not authorized in concluding that during natural breathing the same change takes place. Dr. Edwards found that the quantity of carbonic acid produced by frogs breathing in hydrogen during eight hours, was equal to that furnished in twenty-four hours by frogs immersed in atmospheric air; and mentions an observation of Vauquelin, that blood in contact with hydrogen gives out carbonic acid.

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[g] De l'Influence, &c. p. 456 et seq.

The experiments of Dr. Edwards have tended to elucidate another question, upon which opposite opinions had been entertained. M. Cuvier and Sir H. Davy have maintained that a portion of nitrogen is absorbed during respiration. Jurine was induced to conclude, from the result of his experiments, that nitrogen is generated by respiration; and the same result was obtained by Berthollet and Nysten[b]. Dr. Edwards found, by immersing small animals in a large quantity of air for a limited period, that in many instances there was an evident increase in the quantity of nitrogen, while in others there was a deficiency of it. He observed that the former change took place when the experiments were performed in spring and summer, or when young animals were employed, while the latter occurred during the winter.

The production of carbonic acid varies in the same person at different times: Lavoisier found it greatly increased by exercise and during digestion: Dr. Prout observed it to be increased and diminished periodically.

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[b] Bostock, l. c. p. 105.

The maximum, estimated as equal to 4.1 per cent of the oxygen inspired, occurred about noon: the minimum, equal to 3.3 per cent, occurred towards eight in the evening; from which time till half past three in the morning there was no change.

Atmospheric air is probably the only gas which can be breathed for an indefinite period with impunity. But other gases, as a mixture of oxygen with hydrogen in the proportions of atmospheric air, or nitrous oxide, or oxygen may be breathed for a time without producing mischief. When oxygen nearly pure is breathed, the air expired contains above 10 per cent of carbonic acid. A proportion of nitrogen likewise makes its appearance in the room of an equal bulk of oxygen[i].

Other gases, as carburetted hydrogen, sulphuretted hydrogen, carbonic oxide, and perhaps nitrous gas, when breathed occasion death immediately; but at the same time they produce certain changes in the blood, and therefore kill not merely by depriving the animal of air, but by their specific properties[k].

Other gases again, hydrogen namely, and nitrogen, occasion death when breathed, simply by depriving the animal of atmospheric air.

The preceding sorts of gases have been termed respirable, in as much as they admit of being drawn into the lungs. One other kind still remains, which is termed irrespirable. Carbonic acid, and probably acid and alkaline gases in general, are of this description. The instant that a draught of carbonic acid comes in contact with the aperture of the glottis, the latter is spasmodically closed, so that the effort at inspiration fails. A similar effect takes place when an animal is drowned; and in each case the lungs are found emptied to an extraordinary degree, by the expirations which the animal makes before each renewed and fruitless effort to inspire.

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[i] Phil. Trans. vol. xcviii. p. 267.

[k] Thomson's Chemistry, vol. iv. p. 602.

The air thrown out of the chest in ordinary breathing contains an aqueous vapour, or carries off by evaporation the liquid which lubricates the inner surface of the air-cells and bronchi, of the trachea, the larynx, and the fauces. According to Dr. Hales, the quantity of fluid from this source amounts to about twenty ounces in the twenty-four hours: according to Dr. Menzies, to six ounces: according to Mr. Abernethy, to nine ounces: according to Dr. Thomson, to nineteen ounces. M. Majendie has ascertained that a large proportion of this vapour is derived from the membrane lining the mouth and fauces, and mentions that its quality is readily modified by changes in the state of the blood. If odorous substances be placed in a serous cavity or injected into a vein, the breath acquires their odour. If a solution of phosphorus in oil be thrown into the veins of a dog, its expirations are luminous in the dark, and in the light appear loaded with a thick white vapour, which consists of phosphoric acid[1].

The fine membranous texture of the lungs, which appears to allow an instantaneous passage to the gaseous fluids that are absorbed by or separated from the blood, is readily permeated by the substances which the air holds in solution. Thus the vapour of turpentine when inhaled, finds its way into the blood, and the urine acquires in a short time the peculiar smell of violets, which marks the absorption of turpentine.

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[1] Majendie. Elémens de Phys. tome ii. p. 348.

Respiration has a remarkable consent with the action of the heart. When the pulse is frequent, the breathing is hurried; when the pulse is slow and gentle, respiration is scarcely to be observed: but the means by which this consent is established are unknown.

Respiration is remarkably modified by different affections of the mind. In some states of highly wrought emotion the breathing is hurried and difficult; at the same time the voice is observed to fail. Perhaps both phenomena result from a spasm upon the orifice of the larynx. After violent bodily exertion breathing is more frequent and the inspirations are deeper.

Each act of inspiration requires a special impression through the nerves upon the muscles which dilate the chest. When the spinal chord is divided above the origin of the phrenic nerves, respiration ceases at once, while the heart's action continues without undergoing any immediate change. When the phrenic nerve is irritated in an animal immediately after death, the diaphragm acts. When the phrenic nerves are divided in a living animal, the diaphragm is in great measure paralyzed, and respiration continues through the alternate action of the muscles which raise and depress the ribs. Respiration is always performed with a conscious effort during our waking hours; but we seem not to regulate the frequency of its recurrence or its limits: nevertheless, at will we can enlarge or diminish the area of the chest, and stop, accelerate, or retard the act of respiration. When performed with an effort of attention, breathing becomes fatiguing; but the same happens with any voluntary and habitual action, if we attempt to perform it analytically by directing the attention to every step in its progress.

The influence of the nervi vagi on breathing is imperfectly understood. In general, when these nerves are divided about the middle of the neck, respiration immediately becomes laboured, and the animal dies in a short time. This speedy death probably ensues in consequence of the muscles being paralyzed, which tend to open the passage of the glottis, while the opposite class remains unaffected by the division of the nerves. In an ass in which laboured breathing was produced by cutting through the par vagum, the respiration became easy and natural upon opening the trachea, and continued so for three hours, beyond which the existence of the animal was not prolonged. In a dog in which the par vagum was divided in the neck, the animal survived three days: there was dyspnœa with frequent vomiting, and the stomach was found to have become inflamed. According to the observations of Mr. Brodie, after the division of the par vagum a less quantity of carbonic acid is evolved, the respirations are much diminished in frequency, and the blood in the arteries assumes a darker hue; but its natural colour may be restored by artificially inflating the lungs[m]. Dr. W. Philip ascertained that the dyspnœa produced in dogs and rabbits by the division of the par vagum in the neck, may be relieved by the continued application of galvanism to the chest: the animals nevertheless die: but the surface of the lungs, though reddened generally, shows not the patches of red, nor the bronchial cells the quantity of frothy mucus, usually observed after the division of the nervi vagi.

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[m] Phil. Trans. vol. cii. p. 390.

CHAPTER VI.

OF THE CIRCULATION THROUGH THE BODY.

ALL the phenomena of the circulation which we have hitherto considered may be viewed as preparatory to one important object,—the transmission of arterial blood through the capillary extremities of the aorta, in which it conduces immediately to the support of life. At the same time the blood becomes deteriorated; it loses its florid hue and becomes venous, and toils back to the heart and through the lungs to re-acquire its vivifying properties.

The phenomena of the circulation through the body, which require separate notice, may be classed under the heads of excitement, secretion, the distribution of heat, and absorption.

I. The functions of the nervous and muscular system appear to flag if arterial blood be not propelled in adequate quantity and with sufficient force through their capillary vessels; and although the term excitement may be an improper term to denote the influence which the blood in this instance exerts, and which may be but a part of nutrition, yet the phenomena are so remarkable as well to merit separate consideration. Perhaps they are of the same nature with the following circumstance observed by Dr. Edwards. When frogs are deprived of their hearts, they continue for a time to exhibit voluntary motion; if they are plunged in water, however, they quickly lose all appearance of life, and remain motionless and insensible under mechanical lesion; but upon withdrawing them from the water as soon as they have fallen into this state, they revive and move spontaneously. The exciting or invigorating influence of the atmosphere in this case may serve to illustrate the action of arterial blood upon the organs of warm-blooded animals[a].

1. When from hemorrhage, or from feebleness of the heart's action, arterial blood is thrown with less force and in less volume than usual upon the brain, fainting is ushered in by sensations of languor and feebleness, the ears ring, giddiness ensues, consciousness is lost. If in such a case the nervous system be excited by ammonia held to the nostrils, the heart beats more vigorously; and if the patient be laid in a horizontal posture, the flow of arterial blood to the brain is facilitated: by these means the conditions which produce syncope are removed, and the fainting person revives. It deserves to be remarked, that continued faintness after hemorrhage is to be encouraged as a salutary provision in cases where we cannot directly command the flow of blood; while faintness lasts, the tendency of the blood to coagulate is considerably increased, upon the effects of which the prevention of a return of hemorrhage mainly depends. By repeated or profuse hemorrhage, an exsanguinated condition of the body is produced with alarming debility, which perhaps authorize and recommend, as Dr. Blundell has recently pointed out, the transfusion of blood in such cases, from the veins of a

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[a] De l'Influence, &c. p. 7.

healthy person. The original experiment of Lower, performed about the year 1660, consisted in connecting by means of a tube an artery of one animal with the vein of another: in one instance a healthy man thus received into his system about nine ounces of the blood of a young sheep without suffering from it: but subsequently the operation being employed medicinally met with some notable failures and fell into disrepute. Dr. Blundell has made it appear that the transfusion of blood in animals of different species may be fatal; but has shown that in animals of the same species, if the operation be performed with sufficient adroitness and celerity, the blood may be successfully transferred by means of a syringe[b].

2. When any cause prevents the introduction of atmospheric air or of air containing oxygen into the lungs, the blood is returned unchanged to the left side of the heart, venous instead of arterial blood is thrown into the brain, and consciousness is suspended. This state is termed asphyxia; the feelings with which it commences were ascertained by Pilatre de Rosier, who placed himself in irrespirable air by entering into a brewer's tub while full of carbonic acid evolved by fermentation. A gentle heat manifested itself in all parts of his body, and occasioned a sensible perspiration. A slight itching sensation constrained him frequently to shut his eyes. When he attempted to breathe, a violent feeling of suffocation prevented him. He sought for the steps to get out, but not finding them readily, the necessity of breathing increased, he became giddy, and felt a tingling sensation in his ears. As soon as his mouth

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[b] Medico-Chirurgical Trans. vol. ix. p. 50; and vol. x. p. 269.

reached the air, he breathed freely, but for some time he could not distinguish objects; his face was purple, his limbs were weak, and he understood with difficulty what was said to him. But these symptoms soon left him. He repeated the experiment often, and always found that as long as he continued without breathing, he could speak and move about without inconvenience; but whenever he attempted to breathe, the sensation of suffocation came on[c].

Symptoms very similar appear to have been produced in one experiment of Messrs. Allen and Pepys, when the same three hundred cubic inches of atmospheric air were passed and repassed from eight to ten times through the lungs: the operator became insensible. It deserves remark, that the air which had been employed was found to have gained only ten per cent of carbonic acid; so that life, it appears, would probably be lost before the entire consumption of the oxygen in the air of a confined space. Lavoisier found, however, that by repeatedly withdrawing an animal and reviving it, it might be made to consume nearly all the oxygen of a given quantity of atmospheric air before death. Otherwise birds die before two-thirds, and mice and Guinea pigs before three-fourths of the oxygen of the air is destroyed.

When the influence of causes which produce asphyxia is prolonged, the face becomes bloated and livid, the efforts at respiration cease, and the heart's action gradually fails. The first attempt to be instantaneously made in such a case is to inflate the lungs either with fresh atmospheric air blown with bellows into the nostril, or with air thrown from the lungs of an assistant into those of the asphyxiated person. The body as a general rule should be kept warm; but in cases from the burning of charcoal, the application of cold is said to be useful.

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[c] Journal de Phys. xxviii. p. 418.

The period is not determined at which the power of resuscitation is lost after breathing has been wholly prevented; it probably does not much exceed four or five minutes: about this time life may be considered irrecoverably gone, not merely in consequence of the continued suspension of the energy of the brain, but because the heart appears to lose its irritability when florid blood is not circulating in its vessels. The experiments of Mr. Brodie and of Dr. Wilson Philip, which have been already mentioned, show that after the removal of the brain and spinal chord the heart will continue to act for a length of time, if by means of an artificial respiration it continues to receive florid blood; but if this excitement be withheld, the tendency of the heart to alternate action and relaxation quickly ceases.

3. When nitrous oxide is breathed, although it is uncertain in what degree and by what means the nature of the blood is modified, yet its effects upon the brain are remarkable, and illustrate in a different manner the stimulating effect of the blood. In this instance its power of excitation is increased; and phenomena frequently occur resembling those of intoxication; a degree of vertigo is experienced; the spirits are exhilarated; the muscular force appears increased, and a tendency to violent exertion ensues. When a mixture of oxygen with hydrogen is breathed, a sedative effect appears to be pro-

duced. On breathing oxygen nearly pure, a general glow over the body, with gentle perspiration and quickened pulse, has been observed to take place.

4. When warm water is injected into the veins of an animal after an equal quantity of blood has been drawn from its body, the animal appears enfeebled; its nervous energy appears diminished. There appear to be grounds in the temporary advantage obtained in hydrophobia by this means, according to the experiments of Majendie, for repeating the trial upon animals if not upon human beings attacked with this desperate malady.

5. If air be thrown into the jugular vein of an animal suddenly and in large quantity, a peculiar sound is heard in the chest; the animal utters cries expressive of suffering and quickly perishes. If air be introduced gradually into the veins, frequently no symptom follows. It appears that death may take place from this cause, when in surgical operations at the root of the neck the external jugular vein is accidentally opened. It has happened in such a case that air has been drawn during inspiration into the right cavity of the heart: faintness, cold perspiration, with a peculiar noise in the chest, ensued, and the patient expired in a quarter of an hour[d].

Medicinal substances introduced into the blood in small quantities act promptly and violently; and are thus administered in the veterinary college at Copenhagen. Oily and viscid substances introduced into the blood produce death rapidly, by obstructing the pulmonary capillaries. An American physician, it appears, tried in his own person the injection of a small quantity of castor oil into the blood. Nausea, with a taste of oil in the fauces, an indescribable sensation ascending towards the head, faintness, with spasm of the muscles of the jaws and an imperfect articulation, griping with tenesmus, ensued, and the imprudent experimentalist did not regain his health for several weeks[e].

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[d] Majendie, Journal de Physiologie, tome i. p. 193.

II. From the blood in the capillary vessels of the aorta the various substances of which the body consists, or which are formed upon its surfaces, appear to be separated or secreted[f]. It is not known whether apertures exist in the capillaries specially organized for this purpose, or whether the different 'elements transude through an uniformly porous texture. If size and vermilion be thrown into the aorta so as to inject the whole body, in the serous cavities a quantity of colourless size is found, which must have been strained through very minute orifices, and is supposed to illustrate the mechanism of secretion. But in truth we know very little respecting the intimate nature of this phenomenon. Nor does it much aid our inquiries to classify its products according to their chemical relations: but it is interesting to remark, that although the elements of one secreted substance are readily distinguishable in the blood, while those of another have properties totally unlike that fluid, yet that the quantity of secretion always has reference to the quantity of blood circulating in a part: that when the former is increased, as from the mamma after parturition, the arteries of the part are enlarged: or conversely, that in order to check the increase of a vascular tumour, it is frequently sufficient to tie the main artery leading to it.

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[e] Majendie. Elémens de Physiologie, tome ii. p. 431.

[f] There are probably two exceptions to this statement. The bile appears to be secreted from the capillaries of the vena portarum; and the aqueous vapour of the lungs is perhaps in part supplied from the capillaries of the pulmonary artery.

Secretion furnishes products that are of two kinds; those, namely, which belong to the constitution of organs, being either solid or fluid; and such as are poured out in variable quantities upon the skin or on mucous surfaces, from which they are mostly mechanically removed before their function is attained. The former are instances of nutritive, the latter of functional secretion.

1. No special organization appears necessary for nutritive secretion, or for the separation from the blood of the elements by which the body grows. Capillary vessels that carry red blood are distributed with considerable minuteness in every organ; and it is probable from the phenomena of inflammation, that many channels exist yet finer than the diameter of a coloured globule, with the influence of which we are wholly unacquainted. Plants share this function with animals; and accordingly it seems in great measure independent of the influences peculiar to animal life. The hair and nails are said to grow after death: in a paralyzed limb, growth and the common phenomena of reproduction take place. When the fifth pair of nerves has been divided upon the petrous portion of the temporal line in a rabbit, upon breaking off the crown of an incisor tooth, it is reproduced as rapidly as in animals in which the nerves are entire; and the human mola is sometimes found to have attained considerable development without either brain or spinal chord. Dr. Clarke met with a case, in which after the

birth of a perfect fœtus, another substance was expelled inclosed in a distinct bag of membranes. The membranes consisted of deciduæ, chorion, and amnios, and had a placenta belonging to them, the side of which was attached to the placenta of the perfect child. The mola itself was about four inches in length and three in breadth, of an oval figure, and attached to the placenta by a small and thin funis. There was no vestige of head or neck, no ribs nor clavicle nor scapula: it had four projecting parts, of which one bore an imperfect resemblance to the foot of a child. The surface was covered with the common integuments: the soft parts consisted of an homogeneous fleshy texture, but without any regular or distinct arrangement of muscular fibres, and was very vascular throughout: it contained an os innominatum and an os femoris of the natural size at birth, with a tibia and fibula shorter than natural. A portion of small intestine with a peritoneal covering and mesentery was found, but no glandular substance. It had neither heart nor lungs; neither brain, spinal marrow, nor nerves. The umbilical chord consisted of an artery and vein. Before the internal structure was examined, the navel-string of the perfect fœtus was injected; from whence the injection passed through both placentæ, and then into the substance of the mola[g].

Nevertheless it has been proved, as regards an organ of very delicate fabric, that nutrition is disturbed upon the division of one of the nerves which supply it. M. Majendie found, that when the fifth pair of nerves is divided in the cranial cavity of a rabbit close upon its ap-

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[g] Phil. Trans. vol. lxxxiii. p. 154.

parent origin, the surface of the eye inflames at its upper part, and the upper segment of the cornea becomes clouded. But what is still more remarkable, as tending to show conjointly with the preceding experiment that the influence of nerves upon nutrition is derived in part only from the brain, M. Majendie found that if the fifth nerve be destroyed upon the petrous portion of the temporal bone, where it is involved in the ganglion of Gasser, the entire cornea becomes opake in twenty-four hours, and the opacity daily increases: on the second day the tunica conjunctiva reddens and secretes pus, the iris becomes inflamed and covered with lymph; about the eighth day the cornea begins to ulcerate in its centre and at its edges, the eye bursts, and the humours being discharged, wastes and shrinks to a small nodule[h].

The inflammation of the stomach, which ensues upon the division of the par vagum in animals that survive the operation for three or four days, is probably a phenomenon of the same kind as the preceding.

Nutritive secretion has a strict reference to the physical impressions made upon a part. If a limb, as the arm of a blacksmith, be kept in continual exercise, the muscles become larger, firmer, and more powerful: the bones enlarge, the sinews become stronger. If continued pressure be made upon a surface supported by bone, such for instance as takes place upon the chin in the use of instruments during weakness of the spine, an exostosis is liable to rise from the bone, over which the skin is not tensely extended, but grows so as to form a loose capsule containing it: if the pressure be discontinued, the tumor wastes and disappears; and thus if a limb be kept absolutely at rest, the textures which belong to its composition shrink and become diminished in volume and in strength. Medicines seldom appear directly to affect nutritive secretion; yet mercury in some instances appears to act locally in the resolution of parts thickened by previous inflammation; the liquor potassæ produces general emaciation, and iodine has been thought to exert a specific influence in reducing the enlarged thyreoïd gland.

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[h] Majendie. Journal de Physiologie, tome iv. p. 302 & 176.

2. The saliva, the bile, the urine, the perspiration, are instances of functional secretion. They are liquids which exude upon mucous surfaces, or upon the skin; they are formed, as occasion requires, in different quantities, and they are speedily removed from the surface on which they are produced for some purpose in the vital œconomy. Some of these fluids, as for instance the perspiration and the urine, are probably wholly excrementitious; others, as the saliva, are perhaps wholly re-absorbed; a third set, including the bile, seems to partake of both these characters.

The kind of organ in which functional secretion takes place is greatly diversified. In one instance, as in the skin, an uniform vascular superficies appears to pour out the fluid. In another, as in the crop of the ostrich, numerous orifices are seen upon a surface, each of which leads into a sac of membrane lying in intricate folds, so as greatly to increase the vascular superficies. The lacunæ of the urethra, which are plain shallow pouches of mucous membrane, are among the simplest secreting organs of this description. In a third instance, as in the liver, a fleshy substance presents itself, consisting of numerous similar and coherent particles, which is termed a conglomerate gland. From each separate molecule of the gland, one excretory tube at least issues, the connexion of which with the arteries and veins of the part has hitherto eluded satisfactory observation. In general the excretory tubes of a conglomerate gland coalesce to form a common trunk. Each elementary portion of such a gland resolves itself into blood vessels and excretory tubes. Upon the whole, it appears that a vascular membrane is all which is requisite for secretion, and that the other contrivances, which have been described, are but methods of conveniently packing a large extent of surface in a small compass.

Functional secretion is remarkably under the influence of the nerves. Upon one affection of the mind the tears flow, upon a second the urine, upon another the saliva: yet I found upon cutting the nerves of the kidney in a dog, that in half an hour afterwards a quantity of urine had accumulated in the pelvis of the kidney, and in the ureter, which had been tied. In this as in the former mode of secretion, physical impressions locally applied, seem to have an influence upon the rate of its production. By the removal of the young from its mother the secretion of milk is after a short time entirely suspended, in circumstances where the gland would otherwise have continued its action for an indefinite length of time[1]. The influence of medicines tells immediately upon functional secretion. Many classes of drugs derive their names from the power which they possess of increasing the flow of saliva, of the urine, and the like; and their value, from the connexion which exists between the rate of a secretion and the conditions of other functions. Mr. Brodie ascertained that the secretion of urine does not take place in animals, in which after decapitation the circulation of the blood is sustained by an artificial respiration[k].

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[1] Bostock. Elements of Physiology, vol. ii. p. 404; and Quarterly Journal, vol. i. p. 165, 6.

Three suppositions present themselves, as to the place in which the secretions are formed: either they may be produced in the blood while circulating in the system at large, and be simply separated through the intervention of secreting organs,—or the entire production of a secretion from the blood may be effected by the capillaries in each part,—or the elements of different secretions may spontaneously develope themselves to a certain extent in the blood at large, yet require the influence of the capillary tubes in the part where they are separated, for their complete elaboration. The only fact with which we are acquainted upon this subject is, that after both kidneys have been removed, an animal survives several days, during which the characteristic element of the urine accumulates in considerable quantity in the blood, according to the observations of MM. Prévost and Dumas.

III. When the resemblance was ascertained between the effects of combustion and of respiration upon atmospheric air, the lungs, which were previously supposed to act in cooling the heart, were invested by physiologists with the office of producing animal heat. The difficulty of accounting on this supposition for the equal diffusion of warmth throughout the body was evaded by, and served to confirm the beautiful theory of Crawford. By careful experiments Crawford became satisfied that arterial blood has a greater capacity for heat than venous blood in the ratio of 114.5 to 100. The heat therefore liberated in the lungs during respiration might become instantly latent, and form an unobserved element of arterial blood in its flow through the body; while at the subsequent conversion of arterial into venous blood in the capillaries, the heat would become liberated equally throughout the system. Numerous observations, which have successfully established that the vital heat in different animals, in the same individual, and even in plants, has a close relation to the quantity of oxygen consumed, seemed to place the theory of Crawford beyond the reach of innovation. Recent inquiry concurs with former experience upon the point before us. Dr. Edwards has ascertained that young animals consume in proportion less oxygen than adults, and have a less power of generating heat; and that young animals differ among each other in the power of producing heat, something in the ratio of the oxygen which they destroy. Where respiration is imperfect, as in asthmatic patients, the temperature of the body is lower. Where pure arterial blood does not circulate through the body, as in those, in whom a communication exists between the right and left cavities of the heart, the temperature is below the usual standard.

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[k] Phil. Trans. vol. ci. p. 48.

But the experiments of Mr. Brodie have shown the preceding evidence to be fallacious, and prove that Crawford must have overrated the difference in the capacity for heat of arterial and venous blood, upon which his theory rested. Two rabbits, as nearly alike as possible, were destroyed by decapitation after securing the vessels in the neck: in one the circulation was kept up by means of an artificial respiration; the other was left untouched in the same room at the same temperature. Of these two dead rabbits the first was observed to cool more rapidly than the second: yet in the first the chemical influence of respiration was perfectly sustained, the blood circulating through the lungs from a dark hue assumed the arterial character, that circulating through the body became venous; and the air respired was deteriorated exactly as by the breathing of a living rabbit. Nevertheless, heat was not derived in sufficient quantity from this source to make up for the lowering of temperature produced by the fresh draughts of cool air into the lungs of the dead animal: the thermometer at the expiration of thirty minutes stood at 97° in the rectum of the first, at 98° in the rectum of the second rabbit[1]. Subsequent researches upon this subject by Dr. W. Philip and Dr. Hastings tend to show, that the rapid cooling of the first animal in the experiment detailed may have resulted in part from too large an inflation of the chest; that upon avoiding this excess, the process of cooling appears even to be retarded by artificial respiration, but not to a degree that invalidates the conclusiveness of Mr. Brodie's experiments.

But although the theory of Crawford be thus set aside, it remains possible that arterial blood may prove by some other method the source of animal heat. A general ratio seems to exist between the temperature of parts and the afflux of arterial blood; and the following experiment by Dr. Wilson Philip may serve to show how the decomposition of the latter through an agency, in many instances analogous to the nervous influence, may produce heat. Upon applying the galvanic influence to arterial blood immediately upon being drawn, an evolution of heat amounting to 2° or 3° took place, while the blood assumed a venous hue. The trial was made with the arterial blood of a rabbit; the rise of temperature ceased to show itself in two minutes after the blood began to flow from the vessel, but the change in colour continued to be produced accompanied with an extrication of gas through the galvanic influence. No rise of temperature could be produced in venous blood by the same means[m].

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[1] Phil. Trans. vol. ci. p. 36, et seq.; and vol. cii. p. 380.

The present opinion of physiologists inclines to the belief that the production of animal heat depends upon the nervous influence: yet the best evidence which we possess shows only that temperature may be modified through the nerves, like every other physical endowment of the body. Sir Everard Home found that upon the division of the nerves distributed to the growing antler, its temperature fell immediately several degrees, but rose again a few days afterwards even higher than the temperature of the opposite horn[n]. Sir Everard mentions on the same occasion some curious instances of a partial extrication of heat, which he refers to nervous agency: the oviduct of a frog ready to spawn is two degrees hotter than the heart; and it appears on the authority of Dr. Granville, that during labour the heat of the uterus is sometimes raised to 120°; but a very similar phenomenon has been observed to occur in plants in which no organs analogous to a nervous system have been traced: M. Hubert observed that when the temperature of the atmosphere stood at 21°, a thermometer surrounded with spadices of the arum cordifolium during the process of fecundation stood at 42°.[e]

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[m] Inquiry, &c. p. 242.

[n] Phil. Trans. vol. cxv. p. 7.

Upon the whole, we must admit that the source of vital heat remains unknown. Its remarkable influence upon the human œconomy will be subsequently considered.

IV. The facts which we possess respecting the imbibition of blood-vessels are principally owing to the researches of M. Majendie, from which I extract most of the following observations.

The thigh of a dog, which had previously been stupefied by opium, was separated from the body by the division of every part but the crural artery and vein; into each of these vessels a quill was introduced and tied with two ligatures, between which the vessel was divided: thus a channel was provided for the circulation of the blood, and all other communication between the body and the limb was cut off. Two grains of the upas tieuté were then inserted into a wound in the foot of the separated limb. The poison manifested its effects upon the system in the ordinary time, that is, in about four minutes; and we are given to understand that the animal died within the tenth minute.

A fold of small intestine (this experiment, though founded upon M. Majendie's, was made by M. Ségalas) was drawn out of a wound in the belly of a dog. All the vessels were tied but one large artery. A vein punctured upon the mesentery near the bowel allowed of the escape of the blood thrown into the part by this artery. The lacteal vessels were left entire. The fold of intestine was then tied at both extremities, was opened, and an aqueous solution of alcoholic extract of nux vomica poured into it. During an hour the poison produced no symptoms. The ligature was then removed from one of the veins, and the blood allowed to return to the heart after circulating through the isolated portion of bowel. In six minutes from this time the poison took effect.

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[e] Ellis on Respiration, &c. p. 204.

The preceding phenomena admit of two hypothetical solutions. We may suppose either that the veins possess a special power of absorption through some mechanism not as yet discovered; or that a poisonous substance may find its way into the blood through the coats of the vessels, by virtue of that sort of imbibition or transudation which takes place in dead matter whether organized or unorganized, and which it is analogically probable takes place in living matter as well. The latter supposition has the recommendation of assuming nothing. The following facts appear to bear it out.

If a piece of beef be put in salt, in a few days the saline fluid penetrates the whole mass.

If an animal be opened some time after death, the substances adjoining the gall-bladder are found to be deeply tinged with bile.

If the theca vertebralis of an animal be opened during life or soon after death, a quantity of fluid is found in it; a like quantity of fluid is not found if the examination be delayed till some time after death.

If half an ounce of acidulated water be introduced into the pericardium of a dog killed twelve hours before, and warm water be injected in a continued stream through the coronary arteries so as to flow into the right auricle of the heart, in four or five minutes it gives unequivocal evidence of containing acid.

In an animal that had been killed by the wound of a Javanese poisoned arrow, the parts around the wound became of a brownish yellow colour for the depth of several lines, and took the bitter flavour belonging to the poison.

The preceding instances establish the fact, that in dead animal matter a free imbibition or transudation takes place; so that a substance introduced into it, if capable of being dissolved by its juices, would find its way through the coats of its blood-vessels.

If a drop of ink be placed upon the peritoneum of a living animal, it sinks into it and forms a large circular stain, which at first is confined in depth to the serous membrane, and takes a much longer time to penetrate the subjacent textures.

If a small quantity of ink be introduced into the pleura of a puppy (the experiment succeeds better upon smaller animals), in scarcely an hour the pleura, the pericardium, the intercostal muscles, and the surface of the heart itself, assume a sensibly black tinge.

If the jugular vein of a living puppy be raised from its place without interrupting the circulation, a slip of card being introduced between it and the adjoining parts, and the vein be carefully denuded of the surrounding loose texture, and a thick aqueous solution of the alcoholic extract of nux vomica be placed upon the middle of the card so as to surround and bathe the vein, in less than four minutes the effects of the poison show themselves; at first faintly, but soon after so actively as to require the employment of artificial respiration in order to sustain life.

On comparing these results with the preceding series, it appears impossible to doubt that they depend upon a like transudation taking place in the living body, to that which occurs in the dead. But various circumstances have been ascertained to prevent, or retard, or accelerate this mode of absorption; and it is remarkable that they are consistent with, if they do not materially strengthen, the hypothesis which we have adopted.

Imbibition takes place more readily upon serous than upon mucous membranes, more readily upon very vascular surfaces than upon those which are less so.

The method common among barbarous nations of extracting poison from wounds by suction, is consistent with the supposition that it makes its way by mechanical imbibition.

If a ligature be applied around a limb bitten by a venomous serpent, no symptoms appear as long as the pressure is kept up. But the ligature stops the circulation of the blood, and thus is calculated to prevent the poison being conveyed to the heart and to the brain, if it naturally penetrate by transudation the cavities of the vessels and mix with the blood. If it be true that continued pressure of a ligature, though insufficient wholly to stop the circulation, yet destroys the effect of the poison, this result may be attributed to the gradual introduction of the poison into the system in quantities too small to produce any symptoms.

If a cupping-glass be applied over a poisoned wound, (a fact of practical value that has been recently brought into notice by Dr. Barry,) as long as its pressure is continued no symptoms are shown; if the cupping-glass be removed, the effects of the poison discover themselves; if it be re-applied, their progress is arrested. There can be no doubt that this method acts like the ligature; but it is much more commodious, and may be advantageously employed, not merely in cases of the bite of venomous serpents, but in wounds by rabid animals while preparations are making for the excision or cautery of the wound.

If an animal be artificially placed in a state of plethora by injecting a large quantity of warm water into its veins, a poison introduced into the pleura, which ordinarily shows its effect in two minutes, in half an hour produces no symptoms. Upon drawing a large quantity of blood from a vein, the effects of the poison discover themselves.

If a quantity of blood be drawn from an animal, and be replaced with an equal quantity of water, poisoning takes place as rapidly as if the blood were not thus diluted.

If a quantity of blood be drawn from an animal and no substitution be made, a poison which naturally operates in two minutes produces symptoms in thirty seconds.

In these cases it appears that the degree of distention of the vessels influences the facility with which a poison is introduced into the system: but the same result should take place on mechanical principles, if the mode, by which the poison makes its way, be mechanical transudation through the coats of the blood-vessels.

In therapeutics the principle is well established, that medicines act with increased and more rapid effect after venæsection.

If a solution of prussiate of potass be injected into the pleura, and a solution of sulphate of iron be introduced into the abdomen of a living animal, in general five or six minutes are required for their communication through the diaphragm. But this communication M. Fodera found to be instantaneous, if a current of the galvanic fluid be directed through the diaphragm,—a phenomenon curiously consistent with the effects of a similar influence upon the transmission of liquids through inert capillary tubes.

Such is the mass of evidence upon which the position appears to be established, that transudation takes place in living as well as in dead textures, and serves sufficiently to account for the direct admission of foreign matter in contact with a vascular surface into the circulation. A popular objection to this view is founded upon the fact, that on opening the body of an animal immediately after death, the parts adjoining the gall-bladder are not tinged with bile. But it is easier to imagine that the bile is washed away by the circulating blood, or carried off by the lymphatics as fast as it exudes, than to suppose a new principle in the living body competent to suspend the common law of imbibition by porous substances.

It remains to be determined to what extent this imbibition of the blood-vessels is employed during digestion and in the growth of parts.

CHAPTER VII.

OF DIGESTION.

THE quantity of the blood is continually diminished through secretion, and especially by the loss of fluids separated from it in the lungs, in the kidneys, and upon the skin, no part of which returns into the system. To supply this waste, a fluid is elaborated from the food, which in essential qualities nearly resembles the blood, which is absorbed and poured into the veins by a distinct set of vessels, and mixing with the blood in a short time ceases to be separately distinguishable in it. The process, by which nutritious matter is extracted from the food, is termed Digestion. The food is received into a tube from five to six times the length of the body, in different parts of which it is detained and mixed with secreted fluids that decompose it.

The food is prepared by mastication in the fauces; is carried by deglutition into the stomach, where it is dissolved by the gastric juice; is propelled into the small intestines, where upon mixing with the bile and other secretions, it separates spontaneously into a fluid which wants but little of perfect assimilation to the blood, and refuse matter; the former, termed the chyle, is absorbed by the lacteals; the latter passes into the great intestine, where it becomes fecal, and remains till expelled by a voluntary effort.

The possession of an alimentary canal or cavity is characteristic of animal life. In plants, fluids are absorbed unchanged by capillary orifices, and afterwards elaborated in the vessels of different organs: but even in the lowest animals, with a few exceptions, a digestive cavity is found, or the animal is a bell-shaped sac, into which food is received, and in which it is decomposed. Afterwards the recrementitious part enters the porous structure of the animal, and the refuse matter is expelled through the same orifice at which it was received.

SECTION 1.

Of Hunger and Thirst; of the Mastication of Food, and of Deglutition.

We are led to take food by the appetites of hunger and thirst. If hunger be not gratified, an uneasy sensation of gnawing or dragging occurs which is referred to the epigastrium; if thirst be not slaked, the mouth and throat become dry and parched. It is usual to attribute hunger to an affection of the nerves of the stomach, and thirst to an impression upon the nerves of the fauces and pharynx. But it is far from certain that either of these suppositions is just. Nausea is habitually referred to the stomach, upon the same grounds with the sensation of hunger; yet, according to the experiments of Majendie, after the removal of the stomach in an animal, nausea and the spasm of retching may be produced by the injection of tartar emetic into the veins; and Dr. Gairdner remarked, that in the case of a man who had cut through the œsophagus, several buckets-full of water were swallowed daily, and discharged through the wound, without quenching thirst, which was afterwards found to be abated by the injection of spirits diluted with water into the stomach[a].

It is possible, for any thing known to the contrary, that a person might be hungry without a stomach, and thirsty without a throat. Hunger frequently remains for half an hour or an hour after a hearty meal. Sleep allays it; violent emotions of the mind prevent it. Hunger recurs at stated periods through the influence of habit; at such times if not preceded by much fatigue, the understanding is unusually clear, and there is a general sense of bodily vigour and elasticity: if the gratification of the appetite be withheld, it ceases, and a degree of nausea takes its place, with languor and exhaustion; then hunger returns with painful sensations at the stomach, and as a violent craving, which gets the better of every feeling of aversion and abhorrence, and the vilest food is swallowed with avidity.

The suggestions of the appetite during health, as to the quality and quantity of food, appear to be a true guide to what is wholesome. Every one can distinguish between the hearty meal, which nature prescribes, and the overloaded repast, which stimulating viands enable an epicure to swallow, and for a time to digest. During disease the senses lose their tact, and the appetite frequently longs for objects that would be prejudicial.

The fauces form an organ in which the food is divided, comminuted, and rubbed down with a fluid to the consistence of a pulp; so that it may leave its entire flavour upon the neighbouring sentient surfaces, and be readily conveyed in equal portions along the gullet in the act of deglutition.

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[a] Edinburgh Medical and Surgical Journal, vol. xvi. p. 355.

The vaulted roof of the fauces is the hard palate, around which are set the teeth in their sockets: this part may be considered as fixed during mastication. The lower jaw represents the alveolar processes of the upper maxillary bones, with which it contains an equal number of teeth, and against which it is capable of being pressed in various directions, so that the edges and grinding surfaces of the different teeth may tell upon the food. The tongue, contained within the hollow of the lower jaw, forms the floor of the fauces, and when the mouth is shut, presents a convex upper surface, in contact with the vaulted part of the palate. Three glands on either side, the parotid, the submaxillary, and the sublingual, pour saliva into the mouth, the inner surface of which is lined with a mucous membrane that is continuous at the lips with the skin; and many smaller glandular bodies within the lips and the muscles of the cheek, termed glandulæ labiales and buccales, contribute perhaps to the same office.

The teeth are thirty-two small bones, of which the crown, or base, or body, is covered with enamel, and appears above the gum: the neck of a tooth is that part to which the gum adheres; the root or fang of each tooth is firmly wedged into the substance of the jaw. A tooth is fixed by its fang and neck; the crown is employed in dividing the food, and in articulating vocal sounds.

By means of a longitudinal section the cavity of a tooth is shown; which is naturally open at the extremity of the fang, and ascends through the neck into the crown of the tooth, representing very faithfully its outward form. The cavity is seen to be wrought in the duller coloured substance, or bone of the tooth; and the glistening enamel appears disposed in a thin layer, thickest upon the cutting edge or grinding surface of the crown, and vanishing upon the neck of the tooth.

If a tooth be steeped in diluted muriatic acid, it retains its form, but becomes flexible; the acid dissolves the earthy matter, and leaves the animal substance with which it was combined.

The following is the composition of the bone of teeth:

Animal matter	28.0
Soda with muriate of soda . .	1.4
Carbonate of lime	5.3
Phosphate of lime	61.95
Fluate of lime	2.1
Phosphate of magnesia	1.25
	100.00

The following is the composition of enamel:

Animal matter	2.0
Carbonate of lime	8.0
Phosphate of lime	85.3
Fluate of lime	3.2
Phosphate of magnesia	1.5
	100.0

If a section be made through a tooth and the alveolar process which contains it after a successful injection, neither the enamel nor bony part appears in any degree reddened, but a fine vascular membrane, which enters at the aperture of the fang, is seen to line the whole of the cavity of the tooth; branches from the fifth pair of nerves may be traced to the opening of the fang, upon which the sensibility of a tooth depends.

In this manner the teeth cohere with neighbouring vascular parts. Their mode of life and growth will be afterwards described. At present we have only to consider their mechanical agency in comminuting the food.

The four front teeth in each jaw are termed incisors: the crown has a cutting edge extending transversely, and is wedge-shaped: the fang is single: the two central incisors in the upper jaw are longer than the rest, so as to throw the remaining teeth of the upper jaw rather without or behind those of the lower, till the smallness of the last grinder in the upper jaw causes them to terminate at the same vertical plane.

A cuspidatus, canine, or eye-tooth is found next to the incisors; it is pointed, and larger than the preceding: its fang is single but of great length, and frequently bent at the extremity.

The two sets of cuspidati and incisors form two curved blades, which meet like those of scissors; the incisors and cuspidati of the upper jaw generally fall before those of the lower.

The two teeth, which immediately follow each cuspidatus, have two points upon the crown, one without the other, and the largest external; they are called bicuspides: they have one broad fang fluted at its sides.

The three remaining teeth on each side of each jaw are called molares or grinding teeth: their crowns have five points. The molares of the lower jaw have two fangs, one behind the other; of the upper, three, two of which are external; they rise in a slanting direction. The distribution of the fangs of the upper molares is intended to avoid the antrum of Highmore; but it often happens that one fang, and that more generally belonging to the second molaris, extends into the antrum. In the museum of Albinus there is an instance of the crown of a molar tooth growing into the cavity of the antrum, the direction of the fangs being reversed. The first molaris is the largest; the posterior, or dens sapientiæ, is small: its fangs grow together, and are short. The grinding surfaces of the two sets of molar teeth are exactly opposed to each other.

The strictest relation exists between the form of the teeth and the habits of animals. Thus in the horse, which crops the herbage by bruising and snapping it across, the incisors have broad cutting edges, which meet like the blades of pincers: in the incisor teeth of the beaver, which gnaws through the hardest vegetable fibre, a sharp edge is preserved by the disproportionate distribution of enamel upon the fore part: in the lion the incisors are pointed: in the elephant, front teeth grow from the upper jaw only, and are prolonged into tusks, by the aid of which, with its trunk, the animal tears up the plants that serve for its food. The cuspidati are remarkably large in carnivorous quadrupeds which seize and rend their prey when living; and the character of the head is determined by the prominence of the zygoma to give room for the thick temporal muscle by which the jaws are closed, and by the shortness of the jaws which saves expenditure of power in closing them.

The molares are best developed in graminivorous animals; on this occasion a third substance termed the crusta petrosa, having less hardness than the bone, as the bone has less than the enamel, is wrought into their composition; and as each of these three substances is exposed upon the grinding surface, the latter derives a permanent inequality from their different degrees of hardness favourable to the comminution of the food. The form of the heads of graminivorous quadrupeds is characterized by the length of the jaws in which the massive grinding teeth are set; by the long and flat zygoma, and by the depth and breadth of the branches of the lower jaw, to which muscles are attached, which move it forward and laterally.

The lower jaw consists of the curved piece of bone, in which the sixteen teeth are set, and of a process or branch on either side, which rises nearly at a right angle to be articulated by means of its condyle with the glenoïd fossa of the temporal bone. Each branch is of such a length that when the lower jaw is fully raised, the two rows of teeth are equally pressed against each other, the front teeth locking, the molar teeth simply meeting.

The elementary motions of the lower jaw consist in its simple elevation or depression, in its horizontal movement forward or backward, and from side to side.

1. During the depression or elevation of the lower jaw, the centre of motion falls about the middle of its branches. Or the lower jaw in rising or falling performs part of a vertical revolution, upon an imaginary line drawn horizontally across from side to side through the middle of its branches. The angle of the jaw is carried upwards and backwards; the condyle forwards and downwards, sliding upon the interarticular cartilage, which separates it from the os temporis. The temporal muscles directly raise the lower jaw: the digastricus and other muscles which depress it at the same time retract it; and thus admit of being brought into play even during the action of raising the jaw, in order to limit the effect of the masseter and internal pterygoïd muscles which tend to carry the jaw forward as well as upward.

2. The lower jaw may be carried forward in a plane

parallel to that of the alveoli of the upper jaw, by the action of the external pterygoïd muscles,—aided by the masseters and internal pterygoïd muscles, if their tendency to raise the lower jaw be prevented by the digastrici and various other muscles attached to the os hyoïdes. The muscles last alluded to are calculated simply to retract the jaw, when their effect towards its depression is neutralized by the temporal, masseter, and internal pterygoïd muscles.

3. The lower jaw may rotate horizontally round an imaginary centre, which falls in the middle of a right line joining the two condyles: the masseter of the same side and the pterygoïdei of the opposite concur in giving the jaw this movement with the digastrici and various other muscles attached to the os hyoïdes, the action of which preserves the movement horizontal.

By differently combining these simple motions, all the variety of pressure which the teeth make upon the food is produced.

The os hyoïdes is composed of three slight pieces of bone, a base and two cornua, forming a small horse-shoe figure, within and behind the more capacious curve of the lower jaw: upon this bone the mass of flesh which forms the tongue is supported. The central and largest muscle of the tongue is termed the genio-hyo-glossus; it extends from the symphysis of the jaw to the os hyoïdes in one direction, to the tip of the tongue in the other. Other muscles slant backwards from the lower jaw to the os hyoïdes, which, with the preceding, raise the os hyoïdes, and carry the tongue forward or laterally: the linguales shorten the tongue, the stylo-glossi give it breadth and concavity, the hyo-glossi render it convex:

—so ample is the provision for moving this organ to different parts of the fauces, whether to bruise the softer parts of the aliment against the palate, to mix it with the saliva, to place it under the pressure of the teeth, to assist in determining the taste and other sensible qualities of bodies in contact with the finely organized papillæ on its mucous surface, to urge the masticated food towards the pharynx, or to give articulation to vocal sounds.

The saliva is a limpid fluid like water, but much more viscid: it has neither smell nor taste: its specific gravity according to Dr. Thomson is 1.0038. Its constituents according to Berzelius are as follows:

Water	992.9
Peculiar animal matter . . .	2.9
Mucus	1.4
Alkaline muriates	1.7
Lactate of soda and animal matter	0.9
Pure soda	0.2
	1000.0

The salivary glands are of an ochrey colour, and are composed of numerous molecules of different sizes, connected together by a very firm cellular texture.

The parotid gland is the largest of the three: it occupies the hollow between the mastoïd process of the temporal bone and the branch of the lower jaw; its duct, which is commonly termed the Stenonian duct, passes across the masseter muscle to perforate the buccinator and open upon the membrane of the fauces opposite to the middle molaris of the upper jaw. A small gland termed the socia parotidis adheres to the Stenonian duct in its passage over the masseter. The portio dura traverses the substance of the parotid gland, which appears to derive nerves from this source, from the superficial temporal branch of the third division of the fifth, and from the second cervical nerve.

The submaxillary gland is of an oval form: it is placed above the digastricus between the lower jaw and the mylohyoïdeus muscle: its duct, termed the duct of Wharton, opens upon the mucous surface of the fauces at the side of the frænum linguæ. The nerves of this gland are branches from the gustatory upon which a ganglion is formed.

The sublingual gland is frequently continuous with the posterior portion of the submaxillary gland, is oblong, and placed between the mylohyoïdeus and the membrane of the mouth: its principal ducts or duct open into the duct of Wharton; several smaller ducts open from it into the furrow by the side of the tongue: its nerves are derived from the gustatory.

In the case described by Dr. Gairdner, to which I have already referred, from six to eight ounces of saliva were observed to be discharged during a meal, which consisted of broth injected through the divided œsophagus into the stomach: the quantity is probably greater which is produced under the stimulus of ordinary mastication. With this fluid the food is mixed while undergoing comminution in the fauces. The food acquires at the same time the temperature of the body.

It does not appear that any notable effect is produced upon the aliment through the conjoined influence of the saliva and an elevated temperature. M. Krimer held in his mouth a slice of ham weighing a drachm for three hours. At the expiration of this time the morsel had become white upon its surface, and had gained twelve grains in weight [b]. Perhaps the qualities of the saliva are simply calculated to produce a ready mixture of the various kinds of food triturated with it in the mouth.

The nature of sensations of taste will be afterwards described. The gratification of the sense of taste seems but to whet the appetite of hunger. To allay hunger, deglutition takes place instinctively: we swallow the morsel thrown by the tongue to the back part of the fauces, as soon as its sapid juices have been diffused through the mouth, and its diminished resistance shows it to have attained a state fit for deglutition:—a capacious sac termed the pharynx receives it.

The pharynx opens at the fore part, into the cavities of the nostrils, into the fauces, into the larynx: it is lined by a prolongation of the mucous surface common to these three parts: it is suspended to the basilar process of the occipital bone, and attached laterally to the pterygoïd processes and cornua of the os hyoïdes; thence it becomes narrower to the first ring of the trachea, where the alimentary canal assumes a cylindrical form, and receives the name of œsophagus.

The muscles which raise the os hyoïdes raise the pharynx with it: at the commencement of deglutition all the parts of the throat visibly ascend: the pharynx is drawn upwards to receive the morsel thrust towards it by the pressure of the tongue: and one muscle, the stylo-pharyngeus, which concurs in producing this movement, seems specially intended in addition to expand the pharynx.

Three muscles throw their fibres round the pharynx, which are termed its upper, middle, and lower constrictors: their action is such as to compress any substance that has found entrance into the pharynx, and thus to expel it. But the pharynx is open towards several passages, and the contrivances are remarkable, and well deserve attention, which limit the progress of the food to one direction only, and force it to descend towards the œsophagus, instead of making its escape by the nostrils, the fauces, or the larynx.

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[b] Versuch einer Physiologie des Blutes. Leipsig, 1820.

What is termed the soft palate is a flap of flexible elastic substance about $\frac{1}{4}$ of an inch in thickness and an inch in depth, which hangs as a loose curtain from the posterior edge of the palatine plate of the palate bones. The centre of its unattached margin is prolonged to form the uvula. Laterally two crescentic folds of mucous membrane are reflected from the soft palate to the sides of the tongue and pharynx: between these arches the tonsil gland is placed on either side, which secretes a viscid mucus, that becomes yellow and ropy upon slight inflammation. Each crescentic fold contains muscular fibres; the anterior contains the constrictor isthmi faucium; the posterior, the palato-pharyngeus: these muscles depress the soft palate, and narrow the aperture leading from the fauces.

By these means the communication with the fauces is so straitened, that the pressure of the tongue readily precludes the return of the food into the mouth when the constrictor superior pharyngis contracts.

But the principal office of the soft palate in deglutition consists in protecting the posterior openings of the nostrils: for this purpose it is necessary not merely that this flap of yielding flesh be carried before the food to the back of the pharynx; but that adequate tension be given to it to afford a competent resistance against the pressure of the constrictor superior pharyngis and of the tongue upon the morsel swallowed. Two muscles are provided in addition to those already described to give the tension required to the soft palate, namely, the levator palati mollis and the circumflexus palati: both descend obliquely forwards, the cartilaginous part of the Eustachian tube being interposed between them, from the extremity of the petrous portion of the os temporis: but while the former is directly expanded into the substance of the soft palate, the latter is previously reflected round the hamular process of the sphenoïd bone, and reascends to its insertion: the two muscles thus become opposed in their action, and drawing in different ways upon the soft palate, contribute to extend it over the pharynx behind the opening into the nostrils. Something of the effect of these parts in deglutition may be seen on pressing down the tongue, with the handle of a spoon, and conveying the instrument towards the root of the tongue and the tonsils, when the peculiar sensibility of the back part of the fauces is excited, and an instinctive and irresistible action of deglutition ensues.

The mode in which the respiratory tube is protected under these circumstances can only be well understood in connexion with the anatomy of the larynx. The epiglottis, a thin portion of elastic cartilage, rises vertically at the root of the tongue, and is broad enough when carried backwards to cover the aperture of the glottis: and there is no doubt that in ordinary deglutition this cartilage is pressed down by the food upon the orifice of the larynx. But the epiglottis was removed from animals in the experiments of M. Majendie, and it has been lost by disease in human beings, without any essential prejudice to deglutition. The security of the larynx, as M. Majendie discovered, depends upon the contraction of the muscles which close its aperture, namely, the arytænoïdeus transversus and the arytænoïdei obliqui. While these preserve their power of motion, the loss of the epiglottis is not felt: but if they be paralyzed by the division of the nervi laryngei interni, a part of the food finds its way into the larynx and violent coughing is produced each time that deglutition is attempted, even though the epiglottis have been left entire.

Deglutition consists of three stages; the passage of the food from the mouth into the pharynx, from the pharynx into the œsophagus, from the œsophagus into the stomach.

The movements of pharyngeal deglutition may at any time be performed through a conscious exertion of the will: at times they seem to take place without reference to volition, or uncontrolably. If the movements of deglutition be voluntarily performed several times in succession upon nothing but the saliva, the parts become fatigued, and the operation cannot be immediately repeated. Under ordinary circumstances the pressure of the tongue against the palate-bone, the depression of the soft palate, and the elevation of the pharynx in swallowing are actions distinctly voluntary; but the action of the lower part of the pharynx and of the fibres of the œsophagus is attended with no conscious effort.

SECTION 2.

Of the Alimentary Canal below the Pharynx; of the Spleen, Pancreas, and Liver.

The alimentary canal is a tube composed of slight materials, of a membrane that secretes and absorbs, and of muscular fibres, which encircle it and give motion to its contents.

If a portion of the alimentary canal be injected with size and vermilion through the arteries of the mesentery, and be preserved for a short time in diluted spirit of wine, the several layers of which it consists acquire firmness and become more readily separable. If the portion thus treated be inverted, the inner surface is found to be of an uniform scarlet colour from the minute distribution of capillary blood-vessels through it. Upon making a shallow incision, the same degree of vascularity is not found to penetrate the substance of the part: the superficies to which it is confined may be dissected off as a membrane of extreme delicacy, which forms the inner or mucous tunic of the alimentary canal.

The mucous membrane is of so slight a texture that it would be rent by the passage of the food, but that it coheres firmly with the next or nervous tunic, a thick and tough layer of condensed membrane, wherein the vessels of the alimentary canal subdivide to the size of capillaries, in which dimension alone they are distributed upon the mucous coat. A substratum like the tunica nervea is found in the pharynx and fauces.

In some instances minute glandular bodies are found imbedded in the nervous coat, which open each by a single orifice upon the mucous surface. They are probably of the same structure with the glands described as found in the ingluvies of the ostrich: they are most numerous at the pyloric portion of the stomach, in the duodenum, in the cæcum, and rectum.

The mucous and nervous coats form together the toughest part of the tube when examined in the dead body; they are elastic, but not having the same power of contraction with the outer tunic they are usually thrown into folds, which disappear only at the utmost distention of the alimentary canal, and have a characteristic arrangement in each part: they are disposed as longitudinal plicæ in the œsophagus, as irregular rugæ in the stomach, as flat transverse folds, called valvulæ conniventes, in the small intestine, as shallow rugæ in the great intestine. The mucous membrane of the œsophagus is not very vascular; it is raised into innumerable delicate eminences or papillæ, and frequently has a distinct cuticular lining, which terminates abruptly at the cardia. The mucous membrane of the stomach and small intestines presents the highest degree of vascularity, and is covered with little nodular or shreddy processes termed villi, whence the membrane derives its name of tunica villosa. The mucous coat in the great intestines is of a more soft and pulpy fabric than elsewhere.

The muscular fibres of the alimentary canal are of a grey colour; they are disposed transversely so as to encircle the tubular membranes which they cover. There are three distinct series of these fibres. One invests the œsophagus, and blends above with the fibres of the constrictor inferior pharyngis, below, with the fibres of the stomach: a second begins at the fundus of the stomach, and terminates at the valvula coli: a third commences at the extremity of the cæcum, and terminates at the anus. Towards either extremity of the alimentary canal, where the tube has less importance as an organ of secretion and absorption, and has little use but as an organ of transmission, an outer layer of longitudinal fibres is added, which forms a thick coat investing the œsophagus and the rectum: the former series is lost upon the stomach, the latter ascends to the caput coli in three narrow bands, the shortness of which is the cause of the sacculated form of the colon.

The alimentary canal is supplied with nerves from the par vagum, the sympathetic, and sacral nerves. At the upper part, which the par vagum especially supplies, and at the lower, to which branches of the sacral nerves are distributed, common sensation is manifested in the natural state: the presence of the contents of the tube is felt. The intermediate parts have not the same kind of sensibility: when the small intestines are exposed and handled in a surgical operation, no sensation appears to be excited.

The principle of irritability in the stomach and bowels is imperfectly understood. Upon opening an animal soon after death, the bowels are seen to begin to move; the cold air seems to excite a series of contractions in their circular fibres; at one point the bowels become constricted, then the muscular lacerti of the next portion appear to act, then of the next, and so on in succession. The parts beyond become distended by the propulsion of the intestinal contents, and as they lie in folds their curves become altered, and a kind of progressive motion seems given to the bowels, to which the term vermicular movement is applied: the term peristaltic movement is employed with the same meaning. If a portion of the bowels be detached from the body immediately after death, the vermicular motion is observed to commence in it at intervals; or if it be pinched at any part, the vermicular action follows directly and proceeds slowly from fibre to fibre.

If a portion of the bowel be cut half through, the contraction of the muscular fibres expands the wound and everts the mucous membrane at its edges.

If the nerves be pinched, that are distributed to the alimentary canal below the œsophagus, no movement of the muscular fibre ensues.

If the nervus vagus be pinched in the neck, a sudden shortening and spasm of the œsophagus takes place, and immediately after, a second slower contraction more resembling that of the bowel is observed, which is followed by a slow relaxation and expansion of the part. The stomach near the œsophagus exhibits at the same time a slight action of its fibres.

But whether the fibres of the alimentary canal below the œsophagus are stimulated through their nerves to action, or whether the contact of the contents of the bowel be the physical stimulus which determines its action, and whether the will operate in exciting the peristaltic action of the bowels indirectly, through pressure exerted upon them by the muscles of the abdomen, pelvis, and diaphragm, are at present subjects of mere conjecture; but the latter suppositions appear more probable than the first.

The œsophagus descends before the spine in the posterior cavity of the mediastinum, and enters the abdomen through a specific aperture in the lesser muscle of the diaphragm.

The cavity of the abdomen occupies nearly the whole of the trunk below the junction of the xiphoïd cartilage with the sternum: its extensive surface is divided into an epigastric, umbilical, and hypogastric region in front, and an hypochondriac and lumbar region on either side. The vaulted roof of the abdomen is formed by the diaphragm; laterally its supports are the abdominal muscles, which extend from the spine to the linea alba: the contents of the abdomen rest upon the pubes, or upon the fasciæ, ligaments, and muscles of the lower outlet of the pelvis.

When the cavity of the abdomen is laid freely open, the liver is seen to occupy the right hypochondrium and part of the left and of the epigastrium; the spleen to be placed in the left hypochondrium; between these fleshy viscera, the stomach; and below, the numerous folds of the bowels; but all present a similar glistening and lubricated surface. One ample serous membrane, called the peritoneum, resembling the pleura in its texture and offices, is spread over the whole, confining some of the bowels closely to the spine, but attaching others by long ligaments, so that they freely change their place in the abdominal cavity, as their curves are variously unfolded during the transmission of their contents.

As soon as the œsophagus has entered the abdomen upon the left side of the tenth dorsal vertebra, it opens into a capacious conical sac, called the stomach, near to its large end or fundus, which is lodged in the left hypochondrium. The narrow end of the stomach is drawn up towards the liver by the lesser omentum and capsule of Glisson. The orifice at which the œsophagus opens is termed the cardia of the stomach; the orifice which communicates with the small intestines is termed the pylorus. The stomach lies in the two hypochondria and the epigastrium: when it becomes distended, it rises, revolving upon its cardiac and pyloric attachments, and presenting forwards its unattached convex margin in the epigastrium.

The small intestine is a tube of great length, about four times the length of the body. A short piece when inflated appears cylindrical, but the bowel is really conical. The small intestine continually but insensibly diminishes from the pylorus to the valvula coli in capacity, in thickness, in vascularity, in the size of its villi, in the depth and number of its valvulæ conniventes. The first portion of the small intestine, termed the duodenum, is about twelve inches in length, and closely tied down to the back by the peritoneum, which imperfectly covers it: the duodenum extends first to the right side, then downwards before the right kidney, then obliquely across the spine towards the left. The remaining portion of the small intestine is attached to the spine by a deep fold of doubled peritoneum, called the mesentery, which allows of ample play to the convolutions of the bowels. The root of the mesentery extends from the left side of the second lumbar vertebra to near the right groin: the mesentery conveys the vessels and nerves of the small intestine, the upper two-fifths of which below the duodenum are termed jejunum, the three lower ileum.

The small intestine opens into the great intestine, as the œsophagus opens into the stomach, leaving a sort of fundus termed the cæcum upon the left side. The cæcum varies in length from two inches to six; from its extremity the appendix cæci vermiformis is produced.

The first five feet of the great intestine are termed the colon, and the cæcum is otherwise termed the caput coli. The colon is distinguished by its capacious size, its appendices epiploïcæ, its longitudinal bands, its sacculated appearance; and is divided into an ascending portion, a transverse portion or arch, a descending portion, and a sigmoïdal flexure, which terminates in the rectum.

Mr. Abernethy met with the following curious malformation of the bowels in the body of a boy, which measured four feet three inches in length, was well formed, and had limbs moderately large, yet flaccid, as if wasted by recent disease. The duodenum, jejunum, and ileum, when detached from the body, measured only two feet in length: the great intestines, which were considerably distended, so as to be three inches in diameter, were four feet in length[c].

The spleen is a flattened oval viscus, coloured by the blood which it contains, and adherent to the fundus of the stomach. The splenic artery is large and tortuous, and divides into branches previously to entering the gland, from which five or six small vessels termed vasa brevia are reflected to the stomach. The splenic nerves are derived from the cœliac plexus. It occasionally happens that one or more small glands exactly like the spleen in appearance, are met with in the omentum majus below the spleen.

The texture of the spleen is remarkably brittle, and tears like a congeries of membranous cells filled with clotted blood. Upon making a clean section of a recent spleen taken from a dog or cat, (and I believe that the appearance is common to all warm-blooded animals,) it appears studded with small cells which contain a thick opake whitish fluid.

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[c] Phil. Trans. vol. lxxxiii. p. 64.

It is well known that the spleen may be removed without any serious effect being produced on the system. A dog, from which I removed the spleen twenty-eight months since, became upon recovering from the wound, fatter than before: at present there is no essential difference in its appearance or habits from those of other dogs.

The pancreas is an elongated gland which lies obliquely across the ventral aorta; it has commonly two ducts, the larger of which opens into the duodenum with the ductus communis choledochus; the smaller either opens into the greater, or into the duodenum at an inch distance from it. The pancreas is of the same colour and texture with the parotid and submaxillary glands, and the fluid it secretes accurately resembles the saliva. Its arteries are derived from branches of the cœliac, its nerves from the cœliac plexus.

The form of the liver, the shallow fissures which separate its surface into lobes and lobules, have reference only to its commodious adaptation to the neighbouring parts, and have no physiological interest. The laxness of the ligamentum latum must allow the liver to shift its position in some degree in the various postures of the body. The texture of the liver is brittle: the granules of which it is composed are of the size of mustard-seeds: from each of them one or more fine tubes emerge, by the union of which with those adjoining the right and left hepatic ducts are formed; these again coalesce to form the common hepatic duct.

From the common hepatic duct the cystic duct is reflected at an acute angle; it enlarges, becomes tortuous, and expands to form the gall-bladder. The gall-bladder is contained between the peritoneum and the liver; it consists of a white fibrous coat, and a thin mucous tunic which lies in fine reticular rugæ.

The ductus communis choledochus is the common trunk derived from the cystic and the hepatic duct to the duodenum, which it perforates obliquely at about three inches from the pylorus.

The liver receives blood from two sources. The right and left hepatic arteries are derived from the cœliac; they are small in proportion to the magnitude of the viscus. But the veins which return from the spleen and pancreas, from the stomach and bowels, unite to form a large trunk, termed the vena portæ, which likewise enters the liver at its transverse fissure, and is distributed after the manner of an artery throughout the substance of the liver. The capillary branches of the hepatic arteries and of the vena portæ communicate very freely, so that a fine injection passes very readily from the one system into the other. The veins which carry blood from the liver are termed venæ cavæ hepaticæ: they consist of three or four large trunks, which open from the back and central part of the liver into the ascending cava. Fluids injected into the artery or vena portæ readily pass into the venæ cavæ hepaticæ and into the hepatic ducts. The connection of the vessels and biliary ducts is unknown. The nerves of the liver are derived from the par vagum, the phrenic nerves, and the semilunar ganglia. The absorbents of the liver in part join the thoracic duct in the abdomen, in part perforate the diaphragm, and ascend in the anterior cavity of the mediastinum.

The bile is the secretion of the liver; the gall-bladder appears intended as a reservoir in which the bile is retained when not needed in the small intestine: the bile is supposed to become inspissated during its stay in the gall-bladder through the absorption of its aqueous parts.

The bile is sometimes green, sometimes of a yellowish brown, sometimes nearly colourless. Its taste is not very bitter. It is seldom completely liquid, but usually contains some yellow matter suspended in it. When evaporated to dryness, it leaves a brown matter amounting to about $\frac{1}{11}$ of the original weight[d].

The following are the constituents which Berzelius found in human bile.

Water	908.4
Picromel	80.0
Albumen	3.0
Soda	4.1
Phosphate of lime	0.1
Common salt	3.4
Phosphate of soda with some lime	1.0
	1000.0

It appears that the secretion of bile *may* take place from arterial blood. Mr. Abernethy mentions having examined the body of a female infant, which measured two feet in length, and seemed about ten months old. The muscles of the child were large and firm, and covered by a considerable quantity of healthy fat; and the appearance of the body strongly implied that the child had, when living, possessed much vigour of constitution. The liver was of the ordinary size, but had not the usual inclination to the right side of the body; it was situated in the middle of the upper part of the abdomen, and nearly an equal portion of the gland extended into either hypochondrium. The gall-bladder lay collapsed in its usual situation: it was of a natural structure, but rather smaller than common. It contained about a tea-spoonful of bile, in colour resembling the bile of children, being of a deep yellow; it also tasted like bile: it was bitter, but not so acridly or nauseously bitter as common bile. But in this infant the vena portæ terminated in the inferior cava, and the entire supply of blood to the liver was derived through an hepatic artery larger than common[e].

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[d] Thomson's Chemistry, vol. iv. p. 513.

On the other hand, the recent experiments of M. Simon upon pigeons have shown that when the hepatic artery is tied, the secretion of bile continues; but that if the veins of the porta and the hepatic canals be tied, no trace of bile is subsequently found in the liver: several pigeons survived the latter operation for six-and-thirty hours. In these animals it therefore appears that the secretion of bile takes place from venous blood.

M. Simon observed that when the hepatic ducts alone were tied, the liver became choked up and filled with globules of a green tint; and that this colour was diffused over the whole surface of the organ, and affected the adjoining parts: it is extremely remarkable that in from ten to twenty hours after this experiment, the animals discharged by the anus matter absolutely green, and of the colour of the bile, with which the liver was overloaded;—and it seems not unreasonable to suppose that this appearance resulted from a vicarious secretion from the kidneys[f].

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[e] Phil. Trans. vol. lxxxiii. p. 61.

Perhaps we are bound to attribute the secretion of bile in human beings both to the artery and to the vein: that the venous blood returned from the bowels will serve, we may presume from the experiments narrated; and to employ it as far as it will go, upon this object, is consistent with the wise œconomy of Nature.

SECTION 3.

Of the Formation of Chyme.

The progress of the food along the œsophagus is attended with sensation: it appears to be slow but uninterrupted, unless the solid part of the food be swallowed in morsels too large or hurriedly, when a draught of liquid is required to overcome the painful sense of obstruction which arises, and to facilitate the passage of the aliment towards the stomach by lubricating the surface of the canal. The fibres of the upper part of the œsophagus become relaxed as soon as the food has passed; but those belonging to the lower third of the tube remain firmly contracted for several seconds after its contents are expelled. M. Hallé observed in a woman afflicted by a malady which permitted the interior of the stomach to be seen, that at each entrance of food into the stomach the inner membranes were partially everted, so as to form a circular fold at the margin of the cardia. The sensations excited upon the œsophagus by pressure, laceration, and differences of temperature, exactly resemble those of the skin on similar occasions. This mode of sensibility appears to terminate at the cardia. The stomach seems to have no sensation excited by the contact of the food, unless it be the very obscure sensation of cold, which is referred to the epigastrium upon swallowing liquids at a low temperature.

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[f] Edinburgh Journal of Medical Science, No. I. p. 229.

The stomach easily dilates towards the cardiac extremity. At one-third of its length from the pylorus, a remarkable contraction takes place upon the commencement of digestion, which divides the organ temporarily into two chambers. As the food accumulates within the cardiac portion, the stomach becomes prominent in the epigastrium, the abdomen is distended, the diaphragm cannot descend as readily as before, the inspirations are shorter and more frequent, the exertion of the voice becomes a greater effort, the neighbouring viscera are compressed, and the tendency to evacuate their contents is increased. To prevent the reflux of food along the œsophagus under these circumstances, its muscular fibres are observed to fall into frequent contractions, which for the most part take place at the periods of inspiration, when the pressure upon the abdomen is the greatest.

The food collected in the great end of the stomach is exposed to the influence of varying pressure, of the partial contact of a living surface, and of the secretions of the stomach and fauces at a temperature of 97° or 98°.

Under these circumstances the food appears gradually to dissolve into a thick fluid, termed chyme, which is described as an uniform greyish pulp, more or less viscid, sweetish, acidulated, but varying in its qualities with the nature of the food from which it has been formed. Mr. Brodie mentions that in the stomach of a cat the lean or muscular part of animal food is converted into a brown fluid of the consistence of thin cream: while milk is first separated into its two constituent parts of coagulum and whey, the former of which is afterwards redissolved, and the whole converted into a fluid substance, with very minute portions of coagulum floating in it[g].

Dr. Prout describes the chyme of a dog fed on vegetable food (principally bread) as composed of a semifluid opake yellowish white part, containing another portion of similar colour, but of firmer consistence mixed with it. It showed no traces of a free acid or alkali, but coagulated milk completely, when assisted by a gentle heat. The chyme of a dog fed upon animal food was found by Dr. Prout to be more thick and viscid than the preceding, and its colour more inclining to red. It showed no traces of a free acid or alkali, nor did it coagulate milk, even when assisted by the most favourable circumstances. But these specimens of chyme were taken from the duodenum, and already impregnated with bile[h].

The outer portion of a mass of food lying in the stomach is found to be the first converted into chyme: the chyme is observed gradually to accumulate at the pyloric portion of the organ. Dr. Wilson Philip mentions that when fresh food is taken into the stomach during digestion, it remains for a time distinct from and unmixed with that already partially dissolved; and that in rabbits there is a remarkable difference in the degree of fluidity of the contents of the two extremities of the stomach, the contents of the pyloric portion being uniformly drier than those of the splenic portion.

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[g] Quarterly Journal, No. xxviii. p. 342.

[h] Annals of Philosophy, vol. iii. p. 16.

Some individuals possess the power of throwing up at will without any preceding nausea the contents of the stomach. The effort, by which this is accomplished, consists in making steady pressure with the diaphragm upon the stomach: in the course of a few seconds the mouth is filled with the contents of the stomach. By means of this process rumination may be exactly imitated. If a portion that has been a second time masticated be again swallowed, and another portion of food be forced from the stomach, it is found not to contain that which had been twice swallowed, but to resemble the food first thrown up. In half-an-hour the aliment returned in this way appears to have undergone no change in flavour. After three or four hours what remains in the stomach cannot be thrown up without a painful effort: it is of a fluid consistence and uniformly acid.

About four or five hours may be supposed to be the ordinary time in which the conversion of a meal into chyme is effected. M. Richerand mentions that a woman, who had a fistulous ulcer in the stomach at $\frac{1}{3}$ of its length from the pylorus, habitually discharged chyme through the aperture between 3 and 4 hours after a meal. She was irresistibly led to remove the dressings from the part at this time. The chyme issued rapidly with a noise and an expulsion of gas.

M. Chevreul analyzed gas procured from the stomach of an executed criminal, and found it to consist of

Oxygen	11,00
Carbonic acid . . .	14.00
Hydrogen	3.55
Nitrogen	71.45
	100.00

The quickness of the conversion into chyme depends in a great degree upon the nature of the food. According to the observations of M. Majendie, fat, tendon, cartilage, coagulated albumen, mucilaginous and sugary vegetables resist the action of the stomach longer than fibrinous and glutinous substances. In experiments made by Sir Astley Cooper, fat was found to be digested in the stomach of a dog considerably more rapidly than muscular flesh, than cheese, than skin, cartilage, tendon, or bone, each of which had lost less in weight than the preceding in a given time through the influence of the gastric secretion [1].

An imperfect mastication of food renders the process of chymification slower. Violent exercise immediately upon a meal suspends the production of chyme, and is liable to cause nausea and vomiting. The recumbent position retards the formation of chyme: sleep retards it: gentle exercise with hilarity of mind promotes it.

As the conversion of the food into chyme proceeds, the sensation of fullness and the disinclination to exertion which ensue upon a hearty meal gradually wear off;

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[1] Scudamore on Gout, p. 636.

and the system recovers from the general languor and oppression of other functions, which seem to exist during the commencement of digestion.

Of the various influences to which the food is submitted in the stomach, the contact of a living surface and the pressure of its parietes appear not to be essential to the production of chyme: exposure to the juices of the stomach at the temperature of the body seems alone sufficient for this object.

Spallanzani contrived to throw up by vomiting mechanically excited a tube perforated with holes, containing beef, which he had swallowed four hours before: the flesh was thoroughly soaked with the fluid of the stomach, and its surface was soft and gelatinous: it had moreover wasted from fifty-three to thirty-eight grains [k].

Dr. Stevens found that when a hollow silver sphere, containing raw or cooked flesh or vegetables, and perforated with holes that would admit a crow-quill, was swallowed by a person practised in swallowing pebbles, it was voided in about forty hours perfectly empty.

Mr. Hunter observed that the splenic portion of the human stomach is occasionally found softened, and partially or wholly dissolved, after death. In the latter case, the edges of the opening appear pulpy, tender, and ragged; and the parts adjacent to the stomach, the spleen, the diaphragm, and even the lung, are sometimes affected [l]. No one accustomed to dissection but has verified these observations to a greater or less extent. Dr. W. Philip particularly describes a similar appearance in the stomachs of rabbits when killed after taking food; and remarks the singularity of this occurrence in animals habituated to the digestion of vegetable matter only.

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[k] Dissertations, &c. vol. i. p. 231.

[l] Hunter on the Animal Œconomy, p. 229.

The gastric juice, by which these effects are operated, is a mixture of the saliva with the mucus of the stomach. Chemical analysis throws no light upon its agency.

A M. Pinel is one of those, who can at will throw up the contents of the stomach. Liquid, which was thus procured in the morning before breakfast to the quantity of three ounces was found by M. Thenard to consist of a large proportion of water, some mucus, and salts of soda and lime; at one time the liquid so obtained was acid, at another time it bore no trace of acid.

Spallanzani procured gastric juice from his own stomach by exciting vomiting mechanically: the liquid so obtained was frothy and somewhat glutinous, a little salt to the taste, but not at all bitter. Some of this was put into a glass tube with boiled beef that had been masticated: the tube was then hermetically sealed, and exposed near a fire to a considerable heat, though not perhaps exactly equal to the temperature of the stomach. By the side of this tube was placed another, containing the same quantity of flesh immersed in water. The subsequent appearances in both were the following. In twelve hours the flesh in the former began to lose its fibrous structure, and in thirty-five hours had lost its consistence: to the naked eye it appeared to be reduced to a pultaceous mass, and to have lost its fibrous texture; but a microscope rendered fibres visible. After this semifluid mass had continued two days longer in the gastric fluid, the solution did not seem to have made any further progress, and the reduced fibres were still just as apparent. The flesh did not emit the least bad smell, while that immersed in water was putrid in sixteen hours.

M. Montégre denies that an artificial digestion can be produced in any degree by the gastric fluid taken out of the body; or that the gastric fluid possesses any antiseptic properties. Dr. Fordyce again asserted the latter point, upon the authority of direct experiment; and Mr. Thackrah again denies it, upon the same kind of evidence.

But the coagulation of albuminous fluids is admitted at all hands to be produced by the gastric juice or by the coats of the stomach. What is termed rennet consists of an infusion of the digestive stomach of the calf; by adding this to milk, the albuminous part is converted into curd. Dr. Fordyce mentions that six or seven grains of the inner coat of the stomach infused in water gave a liquor which coagulated more than a hundred ounces of milk[m].

In what degree digestion is under the influence of the nervous system is an inquiry that has led to numerous experiments.

It appears sufficiently established that digestion is independent of the agency of the nervi vagi, when these nerves are divided so as to interfere as little as possible with the functions of other organs besides the stomach.

Mr. Brodie divided the par vagum upon the cardia of the stomach, and found that the operation did not prevent the conversion of the food into chyme.

M. Majendie exposed the par vagum upon the œsophagus immediately above the diaphragm, after taking out a portion of a rib, and divided the nerves. The animal was then compelled to swallow food, which was found to be converted into chyme, and to furnish afterwards an abundant quantity of chyle[a].

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[m] Fordyce on Digestion, p. 58.

When, however, the nervi vagi are divided in the neck, the production of chyme appears very imperfect in those cases wherein it is not entirely prevented; but it is probable that these results ensue indirectly and are to be attributed to the derangement of other functions. The researches of Dr. W. Philip, confirmed by those of MM. Breschet, Edwards, and Vavassour, tend to make it appear that the galvanic influence directed upon the stomach after the division of the nervi vagi in the neck restores its digestive properties; and that the removal of a portion of each nervus vagus interferes with digestion considerably more than the simple division of these nerves. But whatever light has been thrown upon this subject generally by the researches of the physiologists I have mentioned, and by the experiments of Mr. Broughton and of Mr. Cutler, we must admit that it remains involved in great uncertainty.

It appears from experiments by M. Majendie, that when the cerebrum and great part of the cerebellum have been removed in ducks, the instinct of seeking food is lost in every instance, and the instinct of deglutition in many; nevertheless, food that has been introduced into the stomach is found to be digested.

The division of the sympathetic nerves in the neck of rabbits produces no apparent disturbance of any function. The influence of the splanchnic nerves and of the semilunar ganglia has not, that I know of, been put to the test of experiment.

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[a] Majendie, Elémens de Physiologie, tome ii. p. 103.

A history of the functions of the stomach would be incomplete without an account of the means by which it relieves itself of offending matter.

In 1686 it appears that M. Chirac determined by experiment that the stomach is passive during vomiting. Corrosive sublimate was given to a dog upon bread, which was almost immediately thrown up, but nausea and violent retching continued. Upon exposing the cavity of the abdomen, the stomach exhibited a peristaltic motion so feeble as to persuade the operator that the expulsion of its contents could not result from this cause. The wound in the abdomen was then closed; and while the animal continued its efforts to vomit, the finger was introduced and applied to the stomach, which was found to remain free from contraction, and only to be flattened and compressed by the abdominal muscles and diaphragm, at each effort to expel its contents.

Subsequently, however, the opinion of several physiologists seemed to incline to the supposition that the fibres of the stomach are the principal agents in vomiting. Lieutaud and Haller were of this party. But others from the time of Chirac to Hunter continued to hold the first opinion.

" In vomiting," Mr. Hunter observes, " the muscles of the cavity of the abdomen act, in which is to be included the diaphragm; so that the capacity of the abdomen is lessened, and the action of the diaphragm rather raises the ribs; and there is also an attempt to raise them by their proper muscles, to make a kind of vacuum in the thorax, that the œsophagus may be rather opened than shut, while the glottis is shut so as to let no air into the lungs. The muscles of the throat and fauces act to dilate the fauces, which is easily felt by the hand, making there a vacuum, or what is commonly called a suction; so that when all these actions take place together, the stomach is immediately emptied [o]."

The following experiments by M. Majendie confirm the opinion of Chirac and Hunter; they include the notice of an additional fact, which Dr. Haighton had observed, that the division of the par vagum does not prevent vomiting, and present other curious matter for reflection.

If two grains of tartarized antimony dissolved in an ounce and a half of water be thrown into the crural vein of a dog, nausea is produced almost instantaneously; if the stomach be then drawn through a wound in the abdomen, the spasm of retching takes place in the diaphragm and abdominal muscles, but the stomach remains without movement, and no vomiting ensues. If the stomach be then replaced in the cavity of the abdomen, it may be felt by the finger applied to it to remain relaxed, at the time that its contents are expelled through the renewed efforts of retching.

If the nervi vagi be divided, and the emetic substance be introduced as above, nausea and vomiting follow.

If the abdominal muscles be removed leaving the linea alba entire, upon the injection of the emetic substance nausea and vomiting take place, the stomach being compressed between the diaphragm and linea alba.

If the phrenic nerves be divided, and the emetic substance injected, nausea occurs, and vomiting, but more feebly than in the preceding experiment. The diaphragm receives a few twigs from the eleventh and twelfth dorsal nerves, which enable it to act partially in opposition to the abdominal muscles.

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[o] Hunter on the Animal Œconomy.

Finally, if the stomach be removed, and a pig's bladder substituted in its place communicating artificially with the œsophagus, the injection of tartarized antimony into a vein is followed by nausea, by retching, and the expulsion of the contents of the bladder by the fauces.

Animals are observed instinctively to swallow a large quantity of air previously to vomiting, which acts like the draughts of liquid prescribed after an emetic by distending the stomach; so that it resists the spasm of the diaphragm and abdominal muscles, and prevents the necessity for their extreme and painful contraction[p].

The stomach is remarkable for its sympathies. A blow upon the head produces nausea and vomiting; indigestion produces irritation in the lungs, palpitation of the heart, clouded intellect and depression of spirits; a violent blow on the stomach is instantly fatal.

SECTION 4.

Of the Formation of Chyle.

As fast as the chyme accumulates in the pyloric extremity of the stomach, it is carried into the duodenum; so that two or three ounces of chyme form the largest quantity ever found in the part of the stomach adjoining the pylorus. Upon watching the passage of the chyme into the small intestine, the peristaltic action is observed to commence upon the duodenum and to be carried backwards towards the stomach: then a vermicular action commences upon the stomach, and is continued over the pylorus to the duodenum, carrying chyme before it. These phenomena are repeated at intervals, and are not observed to be suspended by the section of the par vagum.

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[p] Mémoire sur le Vomissement.

What is termed the valve of the pylorus consists of muscular fibres triple the thickness of the muscular coat of the stomach, which form a strong circular band projecting into the alimentary canal. The mucous passage is so much the more straitened by the projecting fibres of the valve, that the alimentary canal is externally much narrower at this part than elsewhere.

When air is blown into the duodenum, it readily finds its way into the stomach; but if blown from the œsophagus into the stomach, the latter yields to a great degree of distension before the pylorus allows of the passage of air into the duodenum.

Upon entering the duodenum the chyme becomes mixed with the bile, the pancreatic secretion, and the mucus of the intestine. The latter is viscid, of a salt and acid savour, and quickly renewed, when wiped from the surface of the bowel.

The bile in living animals is seen to exude from the ductus choledochus at intervals, a drop appearing at the orifice and diffusing itself over the neighbouring surface, about twice in a minute. The pancreatic secretion is yet slower in its separation from the gland when thus examined. The bile quickly imparts its sensible qualities to the chyme,—its colour and bitterness. In a short time a spontaneous change is observed to take place in the compound. It separates into a whitish tenacious liquid termed chyle, and a yellow pulp. The former is the recrementitious part of the aliment; the latter, the excrementitious portion, which after undergoing a further change is to be eliminated. Both together are slowly carried along the small intestines, the viscid chyle adhering to the villi, and being detained in the furrows between the valvulæ conniventes; the excrementitious part finally reaching the colon. The chyle gradually disappears in its passage along the small intestines, being absorbed by vessels, which, with their contents, will be described in the following chapter.

According to M. Majendie, there appear upon the contents of the duodenum, when derived from the digestion of animal or vegetable matter containing fat or oil, irregular filaments, sometimes flattened, sometimes rounded, which attach themselves to the villi. But under other circumstances a viscid greyish substance is found, that forms a layer of greater or less thickness, which adheres to the mucous membrane, and seems to contain the elements of the chyle.

The bile has probably a triple use; to assist directly in the production of the chyle; to excite the action of the bowels; while part like the urine may be essentially excrementitious, and blending with the refuse portion of the food may be thus conveniently got rid of.

Mr. Brodie ascertained that when the ductus choledochus is tied in young cats, the formation of chyle is totally prevented. The production of chyme under these circumstances takes place in the stomach as usual; and the small intestines are found to contain a semifluid substance resembling the chyme found in the stomach; but it appears not to undergo the process of decomposition which commonly takes place in the duodenum. It is however found of a thicker consistence in proportion to the distance from the pylorus, and near the termination of the ileum there remains only a consistent substance differing in appearance from ordinary feces.

M. Majendie has subsequently repeated this experiment upon adult animals, and found that few survived the operation: but in two cases, where the animals outlived the experiment for several days, white chyle was formed, and fecal matter produced but not of the usual colour. In these cases the animals had not become tinged with yellow, while in Mr. Brodie's experiments the animals became jaundiced, the tunica conjunctiva acquired a yellow colour, and bile was seen in the urine[q].

These contradictory results are exceedingly perplexing; as it is no less impossible to doubt the exactness of M. Majendie's observations than the fidelity of Mr. Brodie's.

M. Majendie found on introducing a piece of raw flesh into the duodenum of a healthy dog, that in an hour it had been carried to the rectum, with no further change than a discoloration of its surface. Upon fixing a morsel of flesh in the small intestine with a thread, after the lapse of three hours it appeared to have lost about half its weight: the fibrin had been principally removed: what was left was entirely cellular, and remarkably fœtid.

Gas obtained from the small intestines of criminals executed shortly after a repast was found by M. Chevreul to contain no oxygen. In the two first cases in the following table, the repast had preceded execution two hours: in the third, it had preceded death four hours.

	Carbonic Acid.		*Hydrogen.*		*Nitrogen.*		
1st .	24.39	+	55.53	+	20.08	=	100
2nd .	40.00	+	51.15	+	8.85	=	100
3rd .	25.00	+	8.40	+	66.60	=	100

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[q] Quarterly Journal, vol. xxviii. p. 343.

In the preceding section the appearances of the contents of the duodenum are described from Dr. Prout's researches upon the comparative produce of animal and vegetable food. The composition of the two sorts of chyme represented in a tabular view is the following.

	From Vegetable food.	*From Animal food.*
A. Water	86.5	80.0
B. Chyme, &c.	6.0	15.8
C. Albuminous matter		1.3
D. Biliary principle	1.6	1.7
E. Vegetable gluten	5.0	
F. Saline matters	0.7	0.7
G. Insoluble residuum	0.2	0.5
	100.0	100.0

These results were obtained as follows:

Water. The quantity of water present was ascertained by evaporating to dryness a known weight of each of the specimens upon a water-bath.

Chymous Principle, &c. The proportion of this element was determined by adding acetic acid to a known quantity of the mass, and boiling them together for some time. The solid result thus obtained was then collected and dried as before. It consisted partly of a precipitate composed of the digested alimentary matter apparently combined with the gastric secretion, and partly of undissolved and excrementitious alimentary matter. Dr. Prout considered this as the chyme, in which the albuminous principle was not yet so completely formed or developed as to be recognized, mixed with excrementitious matter.

Albuminous Matter, &c. After the above had been removed by filtration, prussiate of potash was added to the acetic solution, which in the chyme from vegetable food produced no precipitate, indicating the absence of albumen; but in the chyme from animal food, a copious precipitate was thus produced. The albuminous matter present in the latter appears to have been partly derived from the flesh on which the animal had been fed.

Biliary Principle. Both chymes were found to contain this principle. It was separated by digesting alcohol on the dried residuum of the chyme. This took up the biliary principle, which was then obtained by driving off the alcohol. It possessed all the usual properties of this principle, except that it appeared to be less easily miscible with water than in its natural state, and to approach more nearly to the nature of a resin or adipocire, changes probably induced in it partly at least by the action of the alcohol.

Vegetable Gluten? The chyme from vegetable food, which consisted of bread, yielded a portion of a principle soluble in acetic acid, and not precipitable by prussiate of potash or ammonia. Hence it was not albumen. It was precipitated by solution of potash, and possessed some other properties analogous to vegetable gluten.

Saline matter. The salts were obtained by incineration, and consisted chiefly of the muriates, sulphates and phosphates, as is usual in animal matters.

Insoluble residuum. This consisted chiefly in the vegetable chyme, of hairs, &c.; in the animal chyme partly of tendinous fibres[r].

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[r] Annals of Philosophy, vol. iii. p. 16.

SECTION 5.

Office of the Great Intestines.

When the refuse portion of the aliment has entered the great intestine, its return into the ileum is prevented by the valvula coli, which is formed of two semilunar flaps containing muscular fibres a continuation seemingly of the small intestine for a short extent into the cavity of the colon. The changes which take place upon the matter introduced into the colon are a further absorption of its fluid parts and an admixture with the secretion of the bowel, from which the excrementitious substance derives its fecal odour which till then is wanting.

By whatever means absorption takes place from the great intestine, it appears probable that much nourishment may be received through this channel. Injections of strong broth into the rectum frequently prove nutritious: the height to which fluids thus injected ascend in the bowel does not seem to have been ascertained.

The difference of the gaseous contents of the great and small intestines consists in the absence of pure hydrogen from the former: in its place a somewhat smaller proportion of carburetted and sulphuretted hydrogen is found.

I extract from Dr. Prout's inquiries the continuation of a tabular view of the contents of the alimentary canal in dogs fed upon vegetable and animal food, which will serve additionally to illustrate the changes produced in different parts of the great intestine.

VEGETABLE FOOD.	ANIMAL FOOD.
From the Cæcum.	*From the Cæcum.*
Of a yellowish brown colour, and of a thick and somewhat slimy consistence. Did not coagulate milk.	Of a brown colour, and very slimy consistence: smell very offensive and peculiar. Coagulated milk.
A. Water, quantity not ascertained.	A. Water, quantity not ascertained.
B. Combination of mucous principle with altered alimentary matters insoluble in acetic acid, and constituting the chief bulk of the substance.	B. Combination of mucous principle with altered alimentary matters insoluble in acetic acid, and constituting the chief bulk of the substance.
C. Albuminous matter, none.	C. Albuminous matter, a distinct trace.
D. Biliary principle, somewhat altered in quantity, nearly as before.	D. Biliary principle, somewhat altered in quantity, nearly as before.
E. Vegetable gluten? none; but contained a principle soluble in acetic acid, and precipitable very copiously by oxalate of ammonia.	E. Vegetable gluten? none; but contained a principle soluble in acetic acid, and precipitable very copiously by oxalate of ammonia.
F. Saline matters, nearly as before.	F. Saline matters, nearly as before.
G. Insoluble residuum, in small quantity.	G. Insoluble residuum, in small quantity.

VEGETABLE FOOD.	ANIMAL FOOD.
From the Colon.	*From the Colon.*
Of a brownish yellow colour of the consistence of thin mustard, and full of air-bubbles. Smell	Consisted of a brownish tremulous and mucus-like fluid, part with some whitish flakes, some-

VEGETABLE FOOD. *From the Colon.*	ANIMAL FOOD. *From the Colon.*
faintish and peculiar, somewhat like raw dough. Did not coagulate milk.	what like coagulated albumen, suspended in it. Smell faintish, and not peculiarly fœtid, like bile.
A. Water, quantity not ascertained.	A. Water, quantity not ascertained.
B. Combination of mucous principle with altered alimentary matters, the latter in excess, insoluble in acetic acid, and constituting the chief bulk of the substance.	B. Combination of alimentary matter in excess with mucous principle, insoluble in acetic acid, and constituting the chief bulk of the substance.
C. Albuminous matter, none.	C. Albuminous matter, none.
D. Biliary principle, nearly as before in all respects.	D. Biliary principle, nearly as before in all respects.
E. Same as in the cæcum.	E. Same as in the cæcum.
F. Salts nearly as above.	F. Salts nearly as above. Only some traces of an alkaline phosphate are observed.
G. Insoluble residuum, less than in the cæcum.	G. Insoluble residuum, a flaky matter in very minute quantity.

VEGETABLE FOOD. *From the Rectum.*	ANIMAL FOOD. *From the Rectum.*
Of a firm consistence, and of an olive-brown colour inclining to yellow. Smell fœtid and offensive. Did not coagulate milk.	Consisted of firm scybala, of a dark brown colour inclining to chocolate. Smell very fœtid. Milk was coagulated by the water in which it had been diffused.
A. Water, quantity not ascertained.	A. Water, quantity not ascertained.
B. Combination or mixture of altered alimentary matters in much greater excess than in the	B. Combination or mixture of altered alimentary matters in much greater excess than in ei-

VEGETABLE FOOD. *From the Rectum.*	ANIMAL FOOD. *From the Rectum.*
colon, with some mucus; insoluble in acetic acid, and constituting the chief bulk of the feces.	ther of the other specimens, with some mucus; insoluble in acetic acid, and constituting the chief bulk of the feces.
C. Albuminous matter, none.	C. Albuminous matter, none.
D. Biliary principle, partly changed to a perfect resin.	D. Biliary principle, more considerable than in the vegetable feces, and almost entirely changed to a perfectly resinous-like substance.
E. Vegetable gluten? none; but contained a principle similar to that in the cæcum and colon.	E. Vegetable gluten? none: but contained a principle similar to that in the cæcum and colon.
F. Salts nearly as before.	F. Salts nearly as before.
G. Insoluble residuum, consisting chiefly of vegetable fibres mixed with hairs.	G. Insoluble residuum, consisting chiefly of hairs.

The analysis of human feces, according to Berzelius, yields

Water	73.3
Vegetable and animal remains	7.0
Bile	0.9
Albumen	0.9
Peculiar and extractive matter	2.7
Slimy matter, consisting of picromel, peculiar animal matter, and insoluble residue	14.0
Salts	1.2
	1000.0[a]

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[a] Thomson's Chemistry, vol. iv. p. 555.

The arrival of excrementitious matter in the lower part of the great intestine produces a sensation leading to the desire to expel it, accompanied with an involuntary contraction of the fibres of the bowel. It commonly happens that the peristaltic action of the fibres of the rectum when first distended with fecal matter is opposed by the contraction of the sphincter externus ani; and for the subsequent expulsion of the feces the bowel has again to be thrown into action by an effort of the will.

But we may presume that the muscular coat of the bowel is not a part that acts voluntarily: what we observe to take place is, that pressure is made upon the bowel by the diaphragm, abdominal muscles, and levator ani, and that its peristaltic action then re-commences. The longitudinal fibres of the rectum tend to prevent a prolapsus of the lower part of the bowel, and assist in retracting it from the matter in progress of expulsion.

The frequency with which the lower bowels are emptied depends upon habit. In general the accumulation of fecal matter takes place in the rectum daily at the same hour: if the usual time for its evacuation is allowed to pass by, the contents of the bowel appear to be thrown back upon the colon; or at any rate the attempt to evacuate the bowels is fruitless. The preservation of health is greatly promoted by attention to the periodical return of the alvine excretion.

SECTION 6.

Of the various Articles of Food.

The first distinction to be drawn among the substances which are taken into the stomach is that some are liquid, others solid. Or a third head might be set apart for treating of the deglutition of aëriform fluids. Most persons, it appears, by practice can attain the power of readily swallowing air; but under ordinary circumstances no advantage is gained by this operation; the air either soon leaves the stomach, or commonly produces uneasy or powerful sensations, often attended with a desire to vomit.

The process of mastication and deglutition, which has been described above, has reference to solid food; liquids reach the stomach in a more simple and rapid manner: each mouthful of liquid is at once thrown back upon the pharynx, and its descent along the œsophagus is promoted by its ready divisibility and lubricated surface.

Some liquids, as water and largely diluted spirits, appear to undergo no change in the alimentary canal, but to be promptly absorbed: and M. Majendie mentions that when a ligature has been tied upon the pylorus the disappearance of the aqueous contents of the stomach is not materially retarded.

Other liquids partly contribute to the formation of chyme; spirits less diluted coagulate the albumen in the secretion of the stomach which is subsequently digested. Milk is curded, and the curd digested: oil seems wholly converted into chyme.

Where there has been a rapid loss of the fluids of the body thirst arises in order that the loss may be replaced: large draughts of plain water are found to have less power of allaying thirst under these circumstances than a smaller draught containing a portion of alcohol. During a repast thirst again is felt, and the drink which is swallowed appears to whet the appetite for solid food:

it has the effect of restoring moisture to the pharynx and œsophagus, and of mechanically favouring the solution of the contents of the stomach. Beer and wine have the additional effect of exciting the organ of taste to a keener relish of the flavour of food, and the stomach to increased energy of digestion. The quantity of aqueous liquid consumed during a meal depends upon habit, and in general is quite unimportant. But dyspeptic persons sometimes find it beneficial to abstain altogether from drinking at and for a short time after a meal.

The solid substances taken into the stomach are derived from various sources. In the ordinary habits of civilized life, the deglutition of mineral substances is restricted to remedial agents that are taken in minute quantities; what changes they undergo, and by what means they are absorbed, is imperfectly known; their absorption is sufficiently proved by the effects which are produced upon the system. But there are instances of savages who consume daily large quantities of an unctuous earth; and although there is no evidence in this case that any part of the mineral element is absorbed, it is nevertheless possible that it may in some manner contribute to the purpose of nourishment. The aranea scenica, according to Mr. Holt, devours sulphate of zinc, and appears to deprive that salt of its acid.

Plants seem interposed between the soil and animal life as laboratories for combining the elements of inert matter into substances capable of being assimilated in the digestion of animals: and animals differ among themselves in the original fitness of their organs for assimilating vegetable matter, so that some appear of an intermediate class in reference to the function of digestion, being intended to animalize vegetable matter, while they are themselves prepared by Nature to be the prey of carnivorous animals. Those which are herbivorous have the alimentary canal considerably more complicated than those which live on animal food; either the stomach is divided into distant chambers, or the colon and cæcum are remarkably developed to fit them for the more elaborate concoction of the food.

The common food of human beings consists either of muscular flesh and fat, of milk and eggs, or of the seeds of certain grasses, of the roots, the leaves, and stalks of different vegetables, and of various kinds of fruit. But the former substances are found to be more nutritious than the latter; and the greatest bodily strength is attained by combining a diet composed chiefly of animal substance with habits of regular and violent exercise.

The proximate principles of animal matter which serve for nutriment are fibrin, albumen, jelly, oil, and osmazome or the extractive matter of meat, which seems to give the specific flavour to the flesh of different animals, but may possibly consist of fibrin only, slightly altered by heat[t].

Gluten, farina, mucilage, oil and sugar, are the nutritive proximate principles of vegetable matter; at the head of which gluten is placed, as a substance containing nitrogen, and more resembling animal matter than any other proximate principle in plants.

It appears that those animals whose nature it is to prefer one sort of food, either animal or vegetable, may gradually be brought to adopt the opposite: it is therefore less surprising that the digestive organs of man, which are placed between those of carnivorous and graminivorous animals, though coming nearer to the latter, should readily accommodate themselves to either kind of nutriment: but even in man the transition cannot be made abruptly without inconvenience. A person accustomed to a large proportion of animal food, on restricting his diet to vegetables is liable to suffer heartburn, a sense of weight and oppression at the stomach, with flatulence, and other symptoms of indigestion, and the bodily frame is rendered less capable of exertion. Yet occasional changes in diet Nature appears to prescribe: in hot weather the appetite is better pleased with fruits and a larger proportion of vegetable food; in cold weather we prefer the reverse: and the same distinction is observed in the habits of the different races of mankind which people the cold or the torrid regions of the globe.

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[t] Thomson's Chemistry, vol. iv. p. 424.

The mixture and variety of diet which the palate and appetite recommend, so far from being injurious to a healthy stomach, is in the highest degree beneficial to it, and serves to keep it in tone and vigour. The prejudicial nature of luxurious diet results from other circumstances; every stomach has its idiosyncrasy, and in a diversity of viands there are some calculated to derange the digestion of one, some of another; and no doubt a succession of savoury dishes is liable to tempt the appetite to unrestrained indulgence. But supposing a moderate discretion, which avoids such viands as are experimentally found to be unwholesome, and such excess as is palpably gross; and there is no question but good living, which presents alternately to the palate every variety of food, soliciting the appetite at one time to one class of viands, at another to a different class, alternately to plain and to highly-seasoned food, is more wholesome than a diet closely restricted to a few simple articles of food.

The perfection of bodily strength is not produced by application to one laborious employment: a vigorous state of the understanding does not result from its confinement to one pursuit; and the health of the digestive organs is promoted by following these analogies.

Dr. Stark made himself the subject of a curious series of experiments upon the relative effects of various simple forms of diet when employed each for a short time exclusively. His researches are principally valuable as tending to show the debility and unwholesome state of body which may be brought on by this practice, and which in his own case led to an untimely death.

Recently M. Majendie has furnished data for a similar conclusion to that suggested by the melancholy history of Dr. Stark, in a series of experiments set on foot to illustrate the unfitness of substances which contain no nitrogen for the nutriment of animals.

A dog fed upon white sugar and water exclusively appeared for seven or eight days to thrive upon this sustenance. He was lively, ate and drank with avidity. Towards the second week he began, however, to lose flesh, though his appetite continued good. In the third week he lost his liveliness and appetite; and an ulcer formed on the middle of each cornea, which perforated it, and the humours of the eye escaped: the animal became more and more feeble and died the thirty-second day of the experiment. Results nearly similar ensued with dogs fed upon olive oil and distilled water; but no ulceration of the cornea took place,—and upon dogs fed with gum, and with butter.

A dog fed with white bread made from pure wheat and with water died at the expiration of fifty days. Another, fed exclusively on military biscuit, suffered no alteration in its health.

Rabbits or Guinea pigs fed upon one substance only, as corn, hay, barley, cabbage, carrots, &c. die with all the marks of inanition, generally in the first fortnight, and sometimes sooner.

An ass fed upon boiled rice died in fifteen days, having latterly refused its nourishment. A cock lived for many months upon this substance, and preserved its health.

Dogs fed exclusively with cheese, or with hard eggs, are found to live for a considerable period, but become feeble, meagre, and lose their hair.

The substance from which rabbits and Guinea pigs can derive subsistence for the longest period appears to be muscular flesh.

When a certain degree of emaciation has been produced by feeding an animal for some time upon one substance, as for instance upon white bread during forty days, the animal will yet eat with avidity different kinds of food offered to it at that period; but it does not regain its strength; it continues to waste, and dies about the same time at which its death would have happened had the exclusive diet been continued[u].

Thus it appears that the selection of the most nutritious kind of food is a point of inferior consequence to the continually varying the nature of the aliment. Two principles are to be attended to in the regulation of diet; that the food be fit to furnish an abundant chyle, and that it duly stimulate the digestive organs. Every one has experienced the difficulty of continually varying the light and restricted diet of invalids, so as to find a grateful alternation of nutritive materials within the narrow limits allowed. In this instance the palate is a true guide to the wants of the stomach.

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[u] Majendie. Elémens de Physiologie, tome ii. p. 494.

An adult person in health appears to require two hearty meals in the day; if subjected to much bodily exertion, a third repast becomes necessary, which otherwise seems to be superfluous. When the stomach is weakened by indisposition, more frequent meals of a lighter kind are requisite.

During infancy and childhood, when a large supply of materials is required to build up the enlarging frame, the appetite is proportionately more keen, the stomach appears to digest simple food more rapidly, and craves more frequent meals. It appears that protracted exertion and imperfect nourishment, if not continued for so long a period as to destroy the tone of the stomach, produce in adults a voracious digestion resembling that of childhood. The digestive organs are fitted by such abstinence for the active service required of them in providing materials for the restoration of the frame.

Mr. Hunter in illustration of this point makes the following extract from Admiral Byron's narrative, who, after describing the privations which he had suffered when shipwrecked on the west coast of South America, incidentally mentions their subsequent effect upon his appetite. "The governor," says Admiral Byron, "ordered a table to be spread for us with cold ham and fowls, which only we three sat down to; and in a short time dispatched more than ten men with common appetites would have done. It is amazing that our eating to that excess we had done, from the time we first came among these kind Indians had not killed us; as we were never satisfied, and used to take all opportunities for some months after, of filling our pockets when we were not seen, that we might get up two or three times in the night to cram ourselves[x]."

Nothing promotes hunger more than temperate exercise in fresh air; yet the appetite is never more vigorous than when a person accustomed to active habits is accidentally occupied for a day with sedentary pursuits. It seems that in the latter case the stomach employs besides its own power the energy which might have been expended in muscular exertion. On the other hand, if exercise unusually violent be taken so as to produce fatigue, the appetite is impaired. According to the theoretical language at present in use, the nervous energy has been in the latter instance disproportionately consumed on the muscular frame, and the stomach has received less than its due supply.

The habits of a literary life materially affect digestion; the neglect of bodily exercise, than which nothing more invigorates the system, and the derivation of nervous energy from other organs to the brains, contribute to impair the vigour of the stomach; at the same time the secretion of bile takes place more sparingly, and a hearty meal finds every part of the alimentary system less capable of its office. The diet in such cases should be moderate, but not exactly simple; the stomach requires excitement to rally its energies, and the temperate use of wine and condiments becomes essential to health; or, as often happens to men of studious habits, who when taking little exercise suppose that they have only to live abstemiously to guard their health, the stomach breaks down, and several years of dyspepsia are the destructive consequence of imprudent literary excesses.

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[x] Hunter on the Animal Œconomy, p. 196.

CHAPTER VIII.

OF THE LACTEAL AND LYMPHATIC VESSELS.

We have next to follow the route of the chyle from the small intestines into the venous system. In the year 1622 Aselli observed upon the mesentery of a dog white lines extending from the bowel towards the liver: on puncturing them a milk-like fluid escaped, and left them transparent vessels. They were termed lacteals, and were justly supposed by their discoverer to absorb the chyle and convey it into the blood. Successive inquiries have shown not merely the origin and termination of these vessels, but that they form part of a system as minutely distributed through the frame as the blood-vessels, and theoretically termed the absorbent system.

At the angle formed by the meeting of the subclavian with the internal jugular vein upon either side of the neck, two or more of these pellucid vessels open, so as to pour their contents into the current of blood passing towards the right auricle. These are the trunks of the absorbent system, which branches from the subclavian veins to every region and organ of the body, but communicates at no other point with the blood-vessels.

The thoracic duct, the largest absorbent in the body, is about three lines in diameter when distended, is of a thin but strong texture, and appears when collapsed semitransparent and of a reddish grey colour. The thoracic duct of a horse, inverted upon the thickest rod it will admit, is shown by the rupture of its lining membrane to consist of a serous inner tunic and an outer fibrous one. It is presumed that a similar distinction of parts exists in human absorbents[a].

Each absorbent vessel contains many valves, consisting of pairs of semilunar folds of membrane attached by their convex edges, as in the veins, and capable of being thrown down by the reflux of its contents so as to close the passage from the trunks towards the branches. Upon the fleshy viscera the resistance of the valves may be overcome by continued pressure, so that mercury will pass from a trunk into the branches, which are there found to be distributed arborescently, with a minuteness so surprising, that the surface of the viscus is entirely covered as with a reticular sheet of quicksilver. These vessels appear to anastomose with a series distributed through the substance of the organ.

In the limbs the absorbent trunks are distributed in two sets; one that accompanies the arteries, another which accompanies the subcutaneous veins: to each artery from three to seven trunks are attached; with the subcutaneous veins from thirty to fifty are associated, which spread over the most protected regions of the limbs.

At particular parts of the body small flattened bodies circular or oval, from three to ten lines in diameter, are found connected with absorbent vessels. These bodies are termed conglobate or absorbent glands. They are very vascular, and have filaments of nerves distributed to them: each appears to consist of a soft fleshy porous substance contained in a membranous capsule: the central part is whiter and firmer than the rest. Generally many absorbent vessels, termed vasa inferentia, enter a conglobate gland upon the side remote from the heart, and a smaller number, termed vasa efferentia, leave it upon the near side.

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[a] Cruikshank. Anatomy of the Absorbing Vessels, p. 61.

Mercury injected into the vasa inferentia appears to fill a series of cells in the absorbent gland, and then escapes by means of the vasa efferentia. Upon an injection with wax, the whole substance of the gland appears to consist of convoluted absorbents irregularly dilated, and which reciprocally communicate.

Two or three small absorbent glands are found at the inner ancle, four or five in the ham, eight or ten at the groin. To the subcutaneous glands at the groin absorbents tend from the leg and thigh, from the pudenda, the abdominal parietes, the nates, and the loins.

A chain of absorbent glands and plexus of absorbent vessels ascends around the iliac arteries to the aorta, continually receiving trunks derived from the neighbouring parts. Opposite to the second lumbar vertebra the absorbents of the mesentery, having passed through a cluster of glands, collect into an oval sac termed the receptaculum chyli; the trunk continued from the receptaculum chyli and from the absorbents of the lower extremities is termed the thoracic duct: it ascends between the aorta and right crus of the diaphragm into the posterior mediastinum, which it obliquely traverses from right to left in its course to the neck: having perforated the fascia cervicalis profunda, the thoracic duct ascends behind the subclavian artery of the left side, and then arches downwards to open by two tubes into the angle at which the subclavian vein joins the internal jugular. In this course the thoracic duct is joined by absorbents from the viscera and neighbouring parts. Absorbent glands accompany these vessels, which are most numerous around the bronchi, where they are of a black colour.

Two or three absorbent glands are found at the bend of the elbow joint, and a cluster surrounds the axillary, subclavian, and carotid arteries. The absorbent vessels of the left side of the head and of the left upper extremity mostly join the thoracic duct, but in part open by two or three separate orifices into the subclavian vein. The corresponding absorbent vessels of the right side open by three or four trunks into the venous angle at the union of the right subclavian and internal jugular veins: these are sometimes joined by a large branch given off from the thoracic duct in the chest.

During the completion of digestion in the small intestines, the absorbent vessels of the mesentery, the receptaculum chyli, and the thoracic duct, are found full of chyle: at other times these vessels contain more or less of a transparent fluid termed lymph, which forms the habitual contents of the remaining larger part of the system.

The absorbent vessels of the mesentery are termed Lacteals, the rest Lymphatics.

Chyle extracted from the thoracic duct of a dog or cat killed during digestion and opened immediately after death varies in appearance as the aliment has or has not contained oil or fat: in the former case its colour is milk-white, in the latter it is nearly transparent. M. Hallé ascertained that coloured substances mixed with the aliment do not colour the chyle.

Chyle is something heavier than distilled water; is of a salt taste, and sensibly alkaline. Soon after being drawn it coagulates, and afterwards separates into three parts; one solid, which rests at the bottom of the vessel; another liquid; and a third substance forming a thin layer on the surface of the latter, and less observable in the semi-transparent than in the opake chyle. At the same time the chyle assumes a reddish tint. The solid substance appears to resemble fibrin; the liquid, serum: the third element is of an oily nature. The chyle contains minute globules of various sizes, but the largest are smaller than those of the blood.

Chyle formed from the digestion of sugar contains but little fibrin. M. Marcet found that chyle derived from vegetable matter contains three times as much carbon as that from animal matter.

Lymph extracted from the thoracic duct of an animal killed after fasting for three or four days, is a fluid nearly transparent, slightly opaline, and tinged with red, but sometimes of a yellow tint: of a saline taste, of the specific gravity compared with water of 1022.28 to 1000. From a large dog it may be collected in the quantity of an ounce and a half.

Lymph spontaneously coagulates, and then appears composed of a fibrous clot, in the irregular cells of which a fluid is contained, which on compression again coagulates. The red tinge of the lymph is increased on its coagulation. If the clot be exposed to oxygen it becomes scarlet; if to carbonic acid, purple. Lymph contains globules resembling but less in size than those of the blood. According to M. Chevreul, the composition of lymph is the following:

Water	926.4
Fibrin	4.2
Albumen	61.0
Muriate of soda	6.1
Carbonate of soda	1.8
Phosphate of lime Phosphate of magnesia Carbonate of lime	.5
	1000.0

Prolonged abstinence in a dog is found to produce a redder colour in the lymph, nearly approaching that of blood.

As much is known of the functions of the lacteals, as the use of the lymphatics remains involved in obscurity. From the commencement of a lacteal to its termination in the venous system, every circumstance relating to it has been displayed and described. I extract from Mr. Cruikshank's work upon the absorbent system, the following account of a successful examination of the origin of these vessels.

"A woman died in consequence of convulsions after lying-in about five in the morning. She had been in perfect health the preceding evening, and ate heartily at supper. The lacteals (upon the mesentery) were distended with chyle, which here formed a firm coagulum. Many of the villi were so full of chyle that I saw nothing of the ramifications of the arteries or veins; the whole appeared as one white vesicle, without any red lines, pores, or orifices whatever. Others of the villi contained chyle, but in a small proportion; and the ramifications of the veins were numerous, and prevailed by their redness over the whiteness of the villi. In some hundred villi I saw the trunk of a lacteal forming or beginning by radiated branches. The orifices of these radii were very distinct on the surface of the villus, as well as the radii themselves, seen through the external surface, passing into the trunk of the lacteal: they were full of a white fluid. There was but one of these trunks in each villus. The orifices on the villi of the jejunum, as Dr. Hunter himself said, (when I asked him as he viewed them in the microscope, how many he thought there might be) were about fifteen or twenty on each villus; and in some I saw them still more numerous[b]."

Thus it appears that the lacteal system originates by numerous capillary orifices upon the villi of the small intestines; and we may presume that the absorption of chyle commences upon physical principles. Accordingly, if the mesentery be exposed immediately after the death of an animal killed during digestion, and the contents of a lacteal be pressed forwards towards the thoracic duct, and a ligature be tied upon the empty vessel, the lacteal is found to become filled again with chyle by the continuance of intestinal absorption. The valves in the lacteal vessels are exceedingly numerous. It is reasonable to suppose them equally numerous in the minute branches of the system. By capillary attraction, the fluid with which it is bathed would ascend in the capillary orifice of a lacteal; and if it rose beyond a single pair of valves, the contraction of the vessel itself would be sufficient to urge it onward to the venous system.

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[b] Cruickshank. Anatomy of the Absorbing Vessels, p. 59.

But this simple explanation of the mechanism of lacteal absorption requires to be somewhat modified. Of the numerous liquid substances which reach the small intestine, the lacteals appear to absorb chyle only.

The experiments of Hunter tended indeed to prove the reverse. When starch and indigo, or milk and water, were injected into the small intestines of sheep and asses, a whitish or blueish liquid appeared to rise in the lacteals. But there is reason to believe that these observations were not made with sufficient exactness. They have been repeated by M. Flandrin, and various physiologists of the present day, and no other substance distinguishable by its odour, colour, or poisonous effects, has been shown to enter the lacteals. When Mr. Hunter saw a white fluid rise in the lacteals after pouring milk into the bowel, we must suppose that some remains of chyle in the small intestine continued to be absorbed; and where the blue liquid was used, the deception probably resulted from the following circumstance. When the lacteals are empty, and are seen against a dusky medium, they appear as blue lines upon the mesentery. I observed this circumstance when repeating the Hunterian experiment upon a rabbit. The lacteals, which when a solution of starch and indigo was first placed in the cavity of the bowel were full of chyle, on being examined half-an-hour afterwards appeared of a clear blue colour, and those present were for an instant satisfied that the experiment had succeeded: but upon placing a sheet of white paper behind the mesentery, the blue tinge disappeared,—the vessels were seen to be transparent and empty. On removing the white paper, they re-assumed their blue colour.

Thus the repetition of the Hunterian experiment leads us to attribute to the lacteals the exclusive function of absorbing chyle. We may conjecture that their orifices are of such a nature as to close on the contact of every other substance.

If the thoracic duct at a proper interval after a meal be exposed in the neck of a dog where it enters the subclavian vein, upon opening the duct chyle escapes with great rapidity. Its velocity is observed to be increased every time that the animal contracts the abdominal muscles, or when the abdomen is compressed by the hand, and to bear a proportion to the quantity of chyme under decomposition in the small intestine. During the first five minutes after opening the thoracic duct in a middle-sized dog, half an ounce of liquid escaped; subsequently the flow of chyle was much slower[c].

The use of the conglobate glands is unknown, but they are observed to be disproportionately larger, and to contain more fluid in early life than at a later period.

Of the lymphatic system beyond the anatomical distribution of its branches nothing is known with certainty.

But we are at liberty to conjecture upon analogy, that lymphatics open upon the mucous surface of the stomach and great intestines, and that they take up a liquid elaborated in those parts from the food. When indeed a dog is forced to drink diluted alcohol during digestion, the blood has the odour of alcohol, the chyle has not. The blood in the veins of the small and great intestines of the horse is found to have the odour of their contents, which the chyle wholly wants. But some principle, it is yet possible, perhaps largely diluted with aqueous liquid, may be taken up by the lymphatics of the alimentary canal.

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[c] Majendie. Elémens de Physiologie, vol. ii. p. 182.

And we may further conjecture with Hunter, from the universality of their distribution, and their fabric every where similar to that of the lacteals, that lymphatics commence with open mouths at every part of the body; and that their office is to take up and carry back to the blood those elements of the body which disappear either to make place for newly secreted matter or without substitution. This conjecture, at any rate, is the most rational which has been proposed as to the use of the lymphatic system, and is remarkably borne out by various circumstances noticed in disease, of which I shall content myself with citing the most conclusive.

Whenever the flesh becomes impregnated with an acrid substance, as for instance with the venereal virus, so that ulceration follows, the lymphatic system alone appears to suffer sympathetic irritation. The lymphatic vessels in such cases commonly become tender, hardened, or their inflamed state shows itself by red lines upon the skin; the lymphatic glands inflame, and matter forms around them.

When a part laden with an acrid substance is removed, it is fair to suppose if any system of vessels seem the exclusive seat of irritation, that they are the parts employed in its absorption.

CHAPTER IX.

OF THE URINARY ORGANS.

The function of the urinary organs may serve to illustrate better than any other case a position assumed by physiologists,—that certain substances require to be continually separated from the blood in order that it may retain its salutary qualities. In other instances where excretion manifestly takes place, as upon the skin, from the lungs, or from the mucous membrane and glands connected with the bowels, it may remain a question whether a second object of equal or greater importance be not contemplated: but in the present instance the exclusive use of a very elaborate contrivance appears to consist in getting rid of a noxious element. As nitrogen exists in a large proportion in the characteristic principle of urine, the kidneys have been supposed to be the vent at which the excess of this principle is discharged.

The kidneys are placed at the sides of the lumbar vertebræ, before the psoæ and quadrati lumborum, and imbedded in fat. The kidney varies in size, and has been known to have been joined to its fellow by an isthmus extending across the aorta.

The kidney is a conglomerate gland, and in the fœtus, and occasionally in the adult, is marked by furrows upon its surface which show its internal division into separate lobes. The kidney is covered on the fore part only by peritoneum, and its proper membranous tunic is proportionately denser than that of the liver or spleen. Its artery, termed the renal or emulgent is, relatively to the size of the gland, the largest in the body: it readily transmits injected fluids into the emulgent veins and excretory tubes. The renal nerves are derived from the semilunar ganglion or solar plexus; several small ganglia are formed upon them: when they are divided in a dog, the animal expresses pain.

On making a section from the external convex edge of the kidney through to the internal concave edge or hilum, the different substances of which the gland is composed become apparent. The outer or cortical part appears extremely vascular, and seems after a successful injection to consist of tortuous vessels alone; processes of the same substance extend towards the hilum of the kidney, between which are contained cones of what seem white convergent fibres. The rounded ends of these cones project at the notch of the kidney, and are termed mammillary processes: their surface is perforated with small apertures, through which the urine may be seen to exude in living animals, and the white fibres appear to be excretory tubes, which rise every where in the cortical substance; the mode of their connexion with the blood-vessels has not been ascertained.

Each mammillary process is inclosed in a loose conical sac termed an infundibulum: each infundibulum opens into a common channel of which there are generally two; one leading from the upper, the other from the lower part of the kidney: these two channels unite to form a capacious conical sac termed the pelvis of the kidney, which gradually narrows, and is continued into a tube termed the ureter, which is cylindrical, being from 3 to 4 lines in diameter when inflated, and leads to the bladder. The infundibulum, pelvis, and ureter, are lined with a fine mucous membrane: their substance is white, fibrous, and of great strength.

The bladder is oviform, the great end looks towards the lower opening of the pelvis, and rests upon the levator ani; the narrow end or fundus looks forward and upward; the anterior and inferior surface rests upon the pubes; the posterior and upper surface is covered by peritoneum, and the bowels rest upon it. Ligamentous bands, which show the former course of the urachus and hypogastric arteries, attach the sides and fundus of the bladder to the navel: the opening of the bladder into the urethra is at its most dependent part, that is to say, at the lowest part of the greatest breadth of the bladder; and the line at which the urethra commences is termed the neck of the bladder; a ligament attaches it to the pubes.

The bladder consists of an intérnal mucous membrane continuous with that of the ureter, but thicker, and of muscular fibres, termed the detrusor urinæ, the inner layer of which is for the most part disposed reticularly; the fibres of the outer layer extend longitudinally from the neck of the bladder to the fundus. The nerves of the bladder are derived from the hypogastric plexus.

The canal of the male urethra first passes through the prostate gland, and from thence to the ligament of Camper is surrounded by a plexus of vessels, and braced to the arch of the pubes by fibres discovered by Mr. Wilson, and named by him the compressor urethræ: the glands of Cowper are placed on either side of the urethra at this part. Beyond the ligament of Camper the male urethra is contained in the corpus spongiosum to the orifice of the penis.

The mucous membrane of the urethra does not appear to be an irritable substance; but it seems not improbable that the tissue which surrounds it is capable of contracting, much in the same manner as the skin. The canal is most capacious at the commencement of the spongy body, where it is termed the bulb of the urethra, and is half surrounded for three or four inches by the fibres of the accelerator urinæ, which are capable of emptying this chamber of the urethra.

The female urethra is short and nearly straight; has no glandular bodies attached to it, but is supported by a compressor urethræ, and is readily dilatable.

The urine during health alone continually varies in quantity and in composition; during cold weather, or when a large quantity of liquid has been received into the stomach, the urine is increased in quantity, and is nearly colourless: during warm weather, when the cutaneous transpiration is greater, less urine is secreted: it is high coloured, and contains a less proportion of water. Various kinds of food increase the flow of urine, or modify the nature of its constituent parts. The average quantity secreted daily amounts to about four pints.

According to Berzelius, the following is the composition of urine:

Water	933.00
Urea	30.10
Sulphate of potash	3.71
Sulphate of soda	3.16
Phosphate of soda	2.94

Muriate of soda	4.45
Phosphate of ammonia	1.65
Muriate of ammonia	1.50
Free lactic acid	17.14
Lactate of ammonia	
Animal matter soluble in alcohol	
Urea not separable from the preceding	
Earthy phosphates with a trace of fluate of lime	1.00
Lithic acid	0.32
Silex	0.03
	1000.00

The ultimate elements of urea, according to Dr. Prout, exist in the following proportion:

Nitrogen	46.66
Carbon	19.99
Hydrogen	6.66
Oxygen	26.66
	29.97

The urine continually exuding into the infundibula of the kidney, urges forward that previously secreted into the bladder. The ureters open obliquely into the bladder, so that the pressure of the urine accumulating in that viscus, tends to close the aperture of the ureters, and to prevent any reflux towards the pelvis of the kidney.

Mr. Bell has remarked that the thick fasciculi of muscular fibres through which the ureters enter the bladder, must contribute during the expulsion of the urine to preserve the obliquity of the entrance by their disproportionate action.

When a certain quantity of urine is contained in the bladder, a peculiar sensation arises, with a desire to evacuate it. By a voluntary effort the levator ani, the abdominal muscles, and the diaphragm contract; and in a few seconds the bladder acts, and the urine flows. There appears to be no necessity for supposing the bladder to be directly influenced by the will. The conscious effort during the expulsion of the urine is not referred to the bladder itself, but to the muscles of the pelvis and abdomen. The fibres of the bladder resemble those of the alimentary canal; when they are pinched immediately after death, a slow contraction of the bladder ensues, and continues for several seconds. When the bladder is laid open by an incision, the contraction which follows the escape of its contents takes place very gradually.

The compressor urethræ we may suppose to act as the sphincter muscle of the bladder.

One of the most remarkable phenomena in the secretion of urine, is the facility with which substances taken into the stomach find their way to the bladder. Sir Everard Home observed, that in seventeen minutes after rhubarb had been swallowed, it could be detected in the urine. The dose consisted of half an ounce of tincture of rhubarb diluted with an ounce and a half of water, and was taken immediately before a breakfast consisting of tea. The test employed was a solution of caustic potash. Upon an examination of animals to which rhubarb had been given in successive doses for several hours before death, the urine was found deeply tinged, and the serum of the blood in the splenic vein, in the inferior cava, and in the right auricle of the heart, showed evidence of containing rhubarb[a]. At this time Sir Everard Home was led to believe that the spleen and the lymphatic system were the route through which rhubarb in the instance cited passed into the blood. But upon pursuing these researches in the year 1815, he found that after removing the spleen and tying the thoracic duct, rhubarb injected into the stomach may be subsequently detected in the urine and in the bile, the contents of the lacteals showing no trace of rhubarb[b].

The preceding circumstances contain, it is obvious, the rudiments of the discovery of the imbibition exercised by the blood-vessels. What appears to have thrown into shade the true explanation of the phenomena described, is the difficulty of detecting the element in the blood, which so freely passed from the stomach into the urine. This anomaly is illustrated by the following observations of M. Majendie.

If a small quantity of prussiate of potash be injected into the veins or absorbed from a mucous or serous surface, it becomes readily distinguishable in the urine, but cannot be detected in the blood. If, however, the experiment be made with a larger quantity, the presence of prussiate of potash in the blood becomes evident. The same difference M. Majendie observed to exist in the facility of detecting prussiate of potash when mixed with urine and with blood out of the body. In the former case the smallest quantity is discoverable by chemical tests, the action of which is by some means obscured in the latter.

The effect of the excision of the kidneys has been already alluded to. MM. Prévost and Dumas found that by the removal of a single kidney from a cat or dog, little effect is produced upon the health; but that within three days after the removal of the second, copious liquid brown evacuations take place, with vomiting of the same matter, rapid small pulse, great constitutional irritation, and laboured breathing: the animal dies between the fifth and ninth day. MM. Prévost and Dumas calculate that a healthy dog habitually produces about a drachm of urea in twenty-four hours. After the preceding operations had been performed, five ounces of blood were found to contain a scruple of urea[c].

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[a] Phil. Trans. vol. xcviii. p. 51.

[b] Ibid. vol. ci. p. 163.

M. Majendie observed, that after the removal of the kidneys, the secretion of bile is extraordinarily increased, so that the stomach and intestines are found to contain bile in large quantities.

M. Ségalas found that the introduction of urea into the blood of animals operates as a diuretic, or promotes the secretion of urine.

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[c] Anderson's Quarterly Journal, vol. i. p. 294.

CHAPTER X.

OF THE SKIN.

THE general integument of the body varies in thickness from about a fifth to a twentieth of an inch. At the commencement of putrefaction the epidermis spontaneously separates, as a thin dry elastic unorganized membrane, from the tough and vascular cutis. Between the epidermis and the true skin, a tenacious moisture is at the same time found, which seems to result from the decomposition of an intermediate substance. This substance, which is found in small quantity in Europeans, appears to be that which, under the name of rete mucosum, gives the characteristic hue to the skin in the coloured families of mankind.

In the Negro or Malay, the cutis is of the same quality as in the European; and the cuticle when separated is scarcely a shade darker: but the rete mucosum,—which commonly admits of being displayed as a gelatinous pigment, adherent either to the inner surface of the epidermis or to the outer surface of the cutis,—or in some cases admits of being reflected as an intermediate, distinct, and coherent membrane,—or in others remains inseparably incorporated with the surface of the cutis, presents a shade yet deeper than the colour of the skin before the removal of the epidermis.

The cutis appears to be a peculiar modification of gelatin. The cuticle seems to be a form of coagulated albumen[a]. In the living body the cuticle may be removed by abrasion, or raised from the cutis by the action of a vesicatory. The colour of the rete mucosum in a Negro may be temporarily removed by immersing a part in water impregnated with chlorine: after a few days the black colour returns with its former intensity.

The skin is marked by furrows of different sizes, of which the largest are upon the palms of the hands or at the joints of the fingers. Specimens of almost all the lesser kinds may be perceived upon the back of the hand. Upon the ridges between the furrows upon the palms of the hands and upon the fingers, numerous little pits are seen, which have the appearance of pores, but are found to be shallow depressions only, which, like the preceding, are made shallower, or disappear when the skin is distended.

The inner surface of the cutis is hollowed into innumerable fossulæ placed close to each other, and varying in size from a twelfth to an eighth of an inch. They receive the subcutaneous layer of fat, upon the quantity of which the sleek or wrinkled appearance of the skin depends.

The skin at certain parts is perforated by two sorts of cylindrical pores, each of which is lined by a fine prolongation of the cuticle. At the bottom of a pore of either sort a small gland exists, which is lodged at the posterior surface of the skin. The substance secreted from the one kind is an oily sebaceous matter, which continually exudes upon the surface of the skin; from glands of the remaining kind the hair grows. Each hair is conical; at its root is a conical cavity, in which the bulb is lodged which forms it. Its chemical composition resembles that of the epidermis; it consists of a dense external crust, and an interior substance of a slighter texture. The pore which transmits each hair is oblique.

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[a] Thomson's Chemistry, vol. ii. p. 470 & 472.

The cuticle is so elastic, that when it has been perforated with a needle the apertures are not distinguishable with a magnifying-glass: it is not therefore surprising, that when it is separated from the cutis, we are unable to discern any thing like a series of pores through which the perspiration may be supposed to exude. Whether there be special apertures for this object, or whether the perspiration transude through the entire substance, is unknown. The cuticle is laid over the cutis like a thin varnish of elastic gum; its main purpose appears to be the prevention of evaporation. How well it serves this end, is shown by the preservation of the moisture of the skin for many days after death where the cuticle has remained entire, contrasted with its rapid desiccation at those parts where the cuticle may happen to have been removed. The object next in importance we may suppose to be the prevention of indiscriminate imbibition or absorption by the vascular surface of the cutis; and finally, we may view the cuticle as interposed to modify the sensations of touch, the acuteness of which would else amount to pain.

The nerves distributed to the skin are derived from the spinal nerves, from the fifth and from the portio dura of the seventh cerebral nerves.

The absorbent vessels of the cutis are so numerous, according to Dr. Gordon, that after a successful injection of them with mercury, the whole surface looks like a sheet of silver: they are very easily injected: their distribution resembles network more than regular ramification[b].

The cutis is exceedingly vascular upon its outer surface, which shows all the furrows and markings that are to be seen before the removal of the epidermis, and is not plain, but raised into innumerable delicate processes or papillæ, that are best developed where the sense of touch is most exquisite.

There is a remarkable analogy between the skin and the mucous membranes. The latter may be viewed as prolongations of the skin over internal surfaces, modified only to suit the difference of place; or the skin may be said to contain the elements of the mucous tubes, but more firmly and closely wrought, and protected by the cuticle, as the latter are protected by the mucus they secrete.

The skin consists of a dense white elastic substratum, analogous to the tunica nervea in the alimentary canal, and of a vascular surface analogous to a mucous or villous membrane. But in the skin the vascular superficies is not separable by any artifice from the thick substratum which supports it.

Let us consider the skin at present in reference to its functions of absorption and transpiration.

Dr. Edwards contrived that a lizard, which had suffered a considerable diminution of weight by exposure to a free current of air for several days, should remain partially immersed in water, which covered its tail, its hind legs, and the hinder part of its body. Under these circumstances the animal re-acquired the weight which it had before lost, and its limbs and body regained their plumpness and former volume[c].

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[b] Gordon's Anatomy, p. 234.

Dr. Edwards confined a snake in air saturated with moisture, removing it and weighing it at intervals: at first it was found to lose in weight; after a time it ceased to become lighter, and was observed to gain in weight.

M. Seguin observed that when the human body is immersed in water at a temperature between 12°.5 and 22°.5 Cent, no loss of weight takes place beyond the usual loss by pulmonary transpiration. Immersion therefore in water at the above temperature, should either prevent cutaneous transpiration, or allow an absorption to take place equal to the loss it occasions. The preceding analogies are in favour of the latter solution. But subsequent researches by the same author seem to show that water in contact with the cuticle of the human body is not absorbed. If the water hold a salt of mercury in solution, it very rarely happens that any evidence of the absorption of the mineral manifests itself even after long and repeated immersion.

The cuticle appears to be the main impediment to cutaneous absorption: if this membrane be removed, absorption takes place rapidly from the surface of the cutis; or if by continued pressure, as during mercurial friction, a substance be mechanically forced through it, absorption does not fail to take place; or if a substance which is of an acrid nature, and calculated chemically to combine with it, be placed in contact with the epidermis, the same result is found to ensue.

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[c] De l'Influence, &c. p. 347.

With respect to the vessels which minister to this function, there is no more reason to believe that the lymphatics absorb poisons or medicines applied to the skin, than that the lacteals have this office in the small intestines. It cannot be doubted that when the impediment which the cuticle offers is removed or overcome, foreign matter in contact with the skin finds its way into the blood-vessels by physical transudation or imbibition.

The action of the skin upon the air is obscurely understood: analogy perhaps would lead us to suppose that an absorption of oxygen takes place at the surface of the body; for the experiments of Mr. Cruickshank and of Mr. Abernethy have shown that carbonic acid is produced when the hand or the foot is confined in atmospheric air. But this subject requires to be yet further elucidated.

A certain quantity of fluid continually transudes through the skin; sometimes it wholly disappears by evaporation: at other times it collects as a liquid upon the surface of the body. In the former case it is termed the Insensible Perspiration; in the latter the Sensible Perspiration.

When collected the perspiration appears to consist of water containing a small proportion of acetic or lactic acid, of muriates of potash and soda, with a trace of animal matter apparently gelatin.

The most unexceptionable experiments perhaps relating to the quantity of the insensible perspiration are those of Lavoisier and Seguin. Upon their testimony the average quantity amounts to eleven grains per minute. During digestion the quantity of cutaneous transpiration appears to be at its minimum. According to

Dr. Edwards, during the six hours before noon the insensible transpiration, *cæteris paribus*, attains its maximum. Sleep would seem to promote it remarkably: a dry state of the atmosphere, exposure to a current of air, diminished barometrical pressure, have a similar tendency.

The influences last named are such as would affect the rate of evaporation from a dead body. Dr. Edwards has founded upon these and similar observations, an apparently just division of the elements of the insensible perspiration into such as are derived from secretion, and such as result physically from the evaporation of the moisture of the skin itself. Upon estimating the comparative loss of weight which frogs suffer when placed at a low temperature in dry air and in air laden with moisture, the proportion of fluid lost by secretion to that lost by transudation appeared to be as 1 : 6.[d] But it is possible that in dry air the quantity of secretion may be greater than in air laden with moisture; the increase of the demand may increase the quantity of the supply, agreeably with a fact respecting the secretion of milk, to which I have already adverted.

At an elevated temperature and during violent exercise the perspiration becomes sensible. No estimate appears to have been made of the actual quantity of liquid produced under these circumstances, or of the ratio in which the different causes alluded to influence the secretion of the sweat. Sir C. Blagden remarked, that on staying for twenty minutes in a chamber heated to 198° the perspiration was so little increased that his shirt was only damp at the end of the experiment[e]. A few minutes of violent exercise at a much lower temperature would have produced a copious flow from the skin.

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[d] De l'Influence &c. p. 334.

[e] Phil. Trans. vol. lxv. p. 119.

The principal object of the sensible perspiration appears to be the reduction of the temperature of the body. The present occasion, therefore, leads us again to consider the subject of vital heat. Heat, it seems, can be produced in all living beings; but while in plants and cold-blooded animals the temperature closely follows that of the media in which they are immersed, in mammiferous animals and in birds a given temperature is sustained, which is termed their standard heat. In human beings the standard heat is about 97°, in viviparous quadrupeds 100° or 101°: the temperature of birds is yet higher,and rises to 107° or 108°.

Extremes of heat or cold appear temporarily to raise or lower the temperature of the body. After staying sixteen minutes in a dry air at 64° Cent, M. Delaroche observed the temperature of the skin to be raised 4°.

During various disorders the temperature of human beings is liable to be raised to a higher standard. In fever the heat has been observed at 104°[f]. M. Prévost witnessed a case of tetanus in which the temperature was elevated 7° Cent above the natural standard. Mr. Cæsar Hawkins mentioned to me having witnessed, that in a person who died within twenty-four hours after an injury of the spinal chord at the lower part of the neck, which crushed it, and produced paraplegia, the thermometer applied to the groin ten minutes before death rose to 111°.

The young of warm-blooded animals have a temperature lower than that of adults. The same difference has been noticed in the human species. M. Breschet ascertained, upon an examination of ten infants within forty-eight hours after birth, that their temperature varied from 34° to 35°.5 Cent.

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[f] Currie's Reports, p. 21 et seq.

There appears to be a remarkable difference in the young of warm-blooded animals as to their power of producing heat. A Guinea pig soon after birth is able to resist a low temperature nearly as well as an adult; but kittens and puppies newly-born lose their temperature rapidly when the external heat is artificially lowered; in a fortnight, however, they acquire the power of evolving heat. This difference bears a relation to the general forwardness of animals. Those which are born with their eyes open, can sustain themselves at a given temperature: the opposite class resemble at first cold-blooded animals, and their temperature falls with that of the surrounding media. A parallel difference is observed in birds, some of which quickly walk and run upon breaking the egg: but others, as for instance the jay, appear hatched before their time, and three or four weeks elapse before they can sustain a standard temperature.

Dr. Edwards, from whose valuable work on the influence of physical agents upon the animal œconomy I have largely borrowed, connects with the preceding remarks an interesting observation of the temperature of a child born at seven months. At this period the existence of the membrana pupillaris ranks the infant with those animals born with closed eyelids; and the temperature of the infant in the case alluded to did not exceed 32° Cent, although the child was well wrapped up and placed before a fire.

The power of producing heat seems to be different at different seasons. Dr. Edwards artificially exposed five sparrows to the influence of a low degree of temperature during three hours at different periods of the year. In February the heat lost averaged at 0°.4 Cent, in July at 3°.62 Cent, in August at 4°.87 Cent. The constitution thus adapts itself to the temperature in which it is placed: when less heat is called for, less heat is habitually produced; and the power of producing it in large quantity is temporarily lost.

Animals that hibernate remain during life unable to sustain a standard temperature against any considerable external cold. In the month of April, the air being at 16° Cent, Dr. Edwards exposed a bat to the temperature of 1° for an hour: in this time its temperature fell from 34° to 14°. Adult sparrows and Guinea pigs under corresponding circumstances lost from 2° to 3° only.

Animals of this description on the approach of winter seek to envelope themselves in substances which contribute to prevent the abstraction of heat and the access of fresh air, and then fall into a torpid state, during which they take no nutriment; and their breathing and the circulation of the blood are so languid, that the performance of these functions has been doubted.

During the torpid state the temperature of the body falls nearly to that of the surrounding media: if the animal be roused, its temperature becomes elevated.

The air of the apartment being 1°.5 Cent, the temperature of a torpid bat was 4°. M. de Saissy roused it by mechanically disturbing it. The animal took an hour to wake: at the expiration of thirty minutes its temperature had risen to 15°, when fully roused, to 27°. The temperature of a dormouse under similar circumstances rose to 36°, its standard heat.

It is remarkable that cold serves as a means of waking hibernating animals, as well as mechanical excitement or a high temperature. M. de Saissy carefully exposed a torpid dormouse at a window looking to the north, when the centigrade thermometer stood at —4°. After a period somewhat longer than in the preceding experiment, the animal was roused, and its temperature rose to 36°. But in this instance the cold which wakes the animal from its torpid state becomes quickly fatal; the temperature falls again, and the animal sinks into a lethargy which is mortal.

The hibernating animal thus perishes of cold like other animals.

In human beings, when sufficient heat cannot be produced to meet the demand from without, the temperature of the body falls, excessive drowsiness and inclination to sleep is felt, which, when indulged in, proves fatal. The frame is then in a condition the least calculated to resist the effects of cold; as heat is habitually produced in greater quantity during the waking state than in sleep[g], during exercise than during repose. Dr. Edwards made the curious remark that the power of enduring and recovering from the effects of cold in young animals, is inversely as their power of producing heat; so that kittens or puppies newly-born can live for two or three days at a temperature of 20° Cent, or even two or three degrees below it.

The accumulation of heat in the system is no less fatal than its rapid abstraction. Copious perspiration and intense thirst, difficulty of breathing, violent pain in the breast, and palpitation of the heart, followed by insensibility, were the symptoms remembered by one who survived the imprisonment in the black hole at Calcutta. Of 146 who shared these sufferings, twenty-three only survived one night's confinement in a crowded dungeon during a tropical night[h]. These fatal effects appear to have ensued in consequence of the hot and confined air becoming saturated with moisture, which prevented further evaporation from the skin, and kept the heat of the body permanently raised above the usual standard. M. Delaroche has ascertained by experiment, that animals placed in an atmosphere charged with moisture cannot support a degree of heat slightly raised above their natural standard.

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[g] De l'Influence &c. p. 474.

Sir C. Blagden observed, when exposed for a few minutes with his clothes on and after a hearty repast to a temperature of 240°, an oppression upon the chest, attended with a sense of anxiety; and the pulse was found to beat 144 pulsations immediately upon leaving the heated room. Upon exposing himself in the forenoon after a moderate breakfast to the temperature of 220° without his shirt, the impression of the heated air was at first painfully disagreeable; but in five or six minutes a profuse sweat broke out, which gave instant relief, and took off all the extraordinary uneasiness: at the end of twelve minutes he left the room very much fatigued, but no otherwise disordered; his pulse had risen to 136.[i]

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[h] Dodsley's Annual Register, 1758. [i] Phil. Trans. vol. lxv. p. 489.

CHAPTER XI.

OF THE BRAIN AND NERVES.

Section 1.

Of the Elements of a Nervous System, and of Consciousness.

The polype, which was divided in the experiments of Trembley, is a thin gelatinous tube about an inch in length, closed at its narrower end. From the margin of its open extremity a fringe of long and slender filaments or tentacula is produced. Every part of the polype is contractile: by means of its tentacula it discriminates and seizes its prey, and conveys it into its digestive cavity; it moves from place to place by alternately attaching either extremity: its structure seems a jelly containing innumerable granules. When turned inside-out the new internal surface acquires the faculty of digestion: when divided, each half becomes a complete polype.

Thus in the lowest animals the properties of life seem equally diffused throughout their substance: each half of a polype may form a portion of a sentient being, or become upon mechanical division individualized.

Cuvier has arranged the diversified species of animals under four classes, which consist, 1. of radiated, and 2. of articulated animals; 3. of mollusca, and 4. of vertebral animals. The polype is nearly at the commencement of this series; but in the same division other animals are found, which have a distinction of organs, and a nervous system. In the star-fish the same element is found as in the human brain, but wrought into a much simpler form, although upon the same general plan.

The material of which a nervous system is formed, is a soft tenacious substance, varying in colour from an orange white to a reddish brown, from a bright yellow to grey or black. When a thin slice of nervous matter is spread upon talc and viewed in a microscope under a drop of water, it is found to consist of an aggregation of minute globules of different sizes, the largest considerably smaller than a globule of the blood. The nervous matter is met with wrought into rounded masses or into flattened chords, to which greater or less firmness is given by sheaths of a delicate membrane, that is distributed in fine layers and processes upon the surface and throughout the substance of parts of the nervous system.

A nervous system appears essentially composed of two parts; of a central organ consisting of two chords, one corresponding with either half of the body, upon which nodular masses are generally placed; and secondly, of other chords or nerves, derived from the central organ to the sentient surfaces or contractile parts of the animal.

In the star-fish (a radiated animal) the central organ consists of a ring of white nervous matter, which surrounds the orifice of the stomach, and gives off opposite to the centre of each ray nerves for its supply.

In the centipede (an articulated animal) the central organ consists of a double chord extending its whole length immediately within the integuments of the abdomen: at the middle of each intersection a nodule is formed upon each chord, from which the nerves of that part are derived. The foremost of this series of pairs of nodules is placed below the œsophagus, and is joined by two filaments to another placed above it; from the latter are given off nerves to the eyes and to the antennæ.

In fresh-water muscles (mollusca) the central organ consists of a nodule on each side of the œsophagus, a double nodule in the foot, and another before the greater muscle of the shell, which are united together by white chords, and distribute nerves to the parts adjoining. Mr. Cæsar Hawkins detected in the fresh-water muscle a striking proof of the identical nature of the nodules found upon different parts of the central organ of the nervous system in the lower animals. In this instance *all* the nodules are of the same colour, a remarkably bright yellow, while the chords which connect them are white.

In vertebral animals the central organ consists of a double chord, or spinal medulla, contained in the vertebral canal, and prolonged into the cranial cavity, where nodules are formed upon it, which are called the brain. From the spinal chord and base of the brain nerves arise in pairs, which are distributed to all parts of the body.

The principle of improvement in the nervous system throughout the ascending scale of animals is the progressive accumulation of nervous matter in larger masses upon that part of the central organ, which is nearest the head or mouth. In proportion as this alteration from the simplest type of organization is effected, the animal becomes more and more individualized; portions separated from it are found to be less capable of independent existence, or the destruction of one organ is observed to produce more derangement of the rest.

Such are the physical elements of a nervous system, and the arrangement of parts belonging to the simplest and to the most complicated. Let us proceed to examine the moral phenomena common to all sentient beings.

We attribute consciousness to animals from the resemblance of their habits to our own. We form definite notions respecting their moral properties by explaining their habits upon the simplest principles, which produce the like in us.

The perception of a sensation is one of the simplest affections of consciousness that we can conceive. Upon analysing this phenomenon we distinguish three elements combined in it: a material impression is communicated to an organ of sense, a change ensues in the physical condition of that organ, and perception follows. Thus in vision, rays of light impinge upon the retina, an affection of the optic nerve and brain ensues, and we see light or colour. Of the three parts into which this phenomenon resolves itself, the last alone is an affection of consciousness: the two first are affections of matter, the antecedence of which distinguishes perception from mental phenomena that resemble it. The conception or imagination of objects in a dream is as vivid and persuasive of their reality as actual perception, but is not like the latter produced by impressions upon our organs of sense.

The term sensation is legitimately used in two senses; either to denote the physical change in our organs which precedes perception, or as synonymous with the term perception. By blending these two ideas, sensation is frequently understood to signify an affection of the mind resulting from material impressions, which is supposed to be the proper object of perception: but the element thus assumed is a logical fiction.

We can imagine a corporeal being, the moral properties of which should be limited to sensation only: it is possible, for instance, that plants feel, although we have every reason to believe the contrary to be the fact. In such a case, however, we have no means of ascertaining the existence of sensibility. Movements in other beings, such as in ourselves are voluntary, constitute our only evidence that they feel.

Volition is another simple affection of consciousness, to define the nature of which we have but to abstract from it the phenomena usually presented to the mind in combination with it. We that are blessed with health habitually connect volition with a sense of muscular effort; but when the limbs are paralyzed, the patient looks at them, and wills in vain their movement: with him the act of volition, like the apprehension of an humorous conceit or any other purely intellectual operation, is unattended with sensation. Volition, in the sense to which it is commonly limited by physiologists, means but *the attempt* to produce muscular action; and the affection of the mind, though during health habitually followed by this result, may take place perfectly, as happens on various occasions including the instance above selected, without a single muscular fibre moving.

Besides sensation and volition, a third element is wanted to compose a scheme of consciousness analogous to our own. Some cause must be supposed capable of determining the occasions, upon which the will energizes: *motives* must exist to actuate the will.

Upon referring to the ordinary operations of our own minds, volition appears to take place whenever we have reason to anticipate a certain degree of gratification or advantage from its exertion. We know by experience the prompt influence of the will upon our muscular frame:—we are able to conjecture with more or less certainty the consequences of different voluntary actions:—and we *will* with a general or precise understanding of what the result will be, and in order to obtain it. A hungry person knows that the food he prepares to eat will gratify his appetite; a drowning person hopes that his cries will bring people to his assistance. But there are other instances in which conscious motives cannot be assigned for voluntary actions. The infant at the breast, or struggling when first plunged into water, employs efforts for its sustenance or preservation *no less voluntary*, than those of the famished prisoner when nourished by his daughter's piety, or of the drowning Roman when he exclaimed, "Help me, Cassius, or I sink." But in the infant the motive which leads to the voluntary effort is not a calculation of advantage, but a spontaneous tendency, a blind inclination, an Instinct.

Instinct appears to consist in a natural tendency to the performance of definite voluntary movements upon the occurrence of certain sensations or states of inward feeling. We have experience of its influence in our own persons at every period of life, and can analyse its nature both under circumstances where it does not admit of control, and in cases where we are capable of modifying or repressing its impulses.

The sudden start which is observed in nervous persons upon hearing an unexpected noise, is an instinctive action of the former kind. The same phenomenon is observed in animals, in which its final cause appears to be their instantaneous removal from uncertain danger.

The expression of the countenance depends upon the instinctive action of its muscles. There are some occasions on which we can resist the natural tendency to wear a smile or a frown upon the face; but there are others on which the practised efforts of a man of the world are insufficient to prevent his thus betraying the expression of transient feeling. The constraint, of which we are conscious as the effort is more or less successful, is like that commonly experienced upon refraining from voluntary actions that have become habitual. We see in the advantage derived to the intercourse of society from this universal language, the reason why nature has implanted so strong an instinctive tendency to its use.

Breathing is another action to which we are led by instinct, in order that when the attention is distracted from this necessity of the body, it may yet sustain no interruption; and throughout life the influence of the instinctive tendency over respiration appears never to be diminished or habitually superseded.

The movements employed in the prehension of food are primarily instinctive, but are afterwards in a great degree performed upon reflection. Nevertheless, the contact of the food resting upon the root of the tongue always excites an instinctive act of deglutition, which we may suppose intended to ensure the protection of the respiratory organs.

Many writers oppose instinctive to voluntary actions, and suppose that in the former a principle different from volition directs the muscular effort. I am induced to prefer the account of instinct which I have given, as it seems to me both more simple and more consistent with observation.

Instinctive actions are attended with a conscious effort like those which we will upon reflection, but unlike the action of the heart or stomach, over which the will exerts no influence.

As we are able at our pleasure to modify the expression of the countenance, so can we at any time instantaneously assume the control of breathing, and suspend it or accelerate it. Or if we have breathed for a short time by a conscious effort of the will with measured inspirations, we can allow the function to return to its usual rate without any abrupt transition as from one mode of action to a different mode.

One nerve alone is employed for the transmission both of the instinctive impulse, and of the deliberate influence of the will. The diaphragm is rendered equally insensible to either stimulus, when the phrenic nerve is divided: and upon cutting through the portio dura of the seventh pair upon the face, I ascertained that the muscles which it supplies are paralysed for every mode of action.

Among the various examples of instincts peculiar to animals, the industry of the bee furnishes a theme of common admiration. The principle, by which the bee is led to model its cell with mathematical precision, is probably the same with that which leads the infant to its first inspiration. The insect in all likelihood foresees no advantage from its labour; and the skill which it displays marks but the curious wisdom of its Creator, who moulded the living being for sensation and enjoy-ment, yet directed its blind propensities with perfect art and unerring accuracy to important ends.

The instincts of animals in some degree give place to other principles. The young of every species have a remarkable tendency to imitate the habits of those around them. The human infant quickly adopts something of the manner and expression of those who nurture it. In singing-birds the influence of this principle is so remarkable, that if brought up exclusively with birds belonging to another species, they learn the song of their companions instead of the notes proper to their kind[k].

Memory is shown to belong to animals on numerous occasions; as for instance, by their caution in shunning places where they have been disturbed, to which their instincts would lead them to return. To the same principle may be attributed the seeming wariness of old animals in a wild state. Instances of apparent contrivance in animals result probably from the recollection, and consist in the repetition of former fortunate accidents.

But whatever vestiges we observe of human faculties in animals,—a susceptibility of attachment and of aversion, appetites like those of man, and a seeming sagacity in providing for their wants,—they yet exhibit nothing that can strictly be compared with human reason. Animals appear to share the same first impulses with human beings, but not having the power to reflect, or deliberate, or to conceive the combination of means for the attainment of an end, they derive little advantage from experience, and want that capacity of indefinite improvement, which alone might vindicate for Man an exclusive claim to Immortality.

[illegible]
Ph. [illegible]
Zoolog [illegible]
It is shown
animals

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[k] Phil. Trans. vol. lxiii. p. 254.

SECTION 2.

Anatomy of the Brain and Spinal Chord in Man.

The central organs of the human nervous system are contained in the cranial cavity and vertebral canal. We trace in the external convexity of the bones of the head, in their sutural union, and in the different density of the three layers of which they for the most part consist, a provision to protect the brain against external injury. In the numerous joints of the spine, and in the limited movement allowed to each, we trace a provision for the equable distribution of pressure upon the contents of the vertebral canal during its necessary flexions.

Upon partially removing the cranial bones or the arches of the spine, the outermost of three membranes is brought into view. The dura mater is a thick fibrous membrane of great strength; which in the cranial cavity serves as a periosteum to its concave surface, but which in the vertebral canal, where it receives the name of theca vertebralis, forms a flattened cylindrical tube of less diameter than the arch of bone, from the periosteum of which it is separated by ligamentous, cellular, and adipose texture. The want of adhesion of the theca vertebralis to the bones that contain it is another provision for the security of its contents. Across the cranial cavity the dura mater throws membranous processes, which are interposed between the divisions of the brain, and serve to support its parts. In the tense edges of these septa, or in other parts of the dura mater, channels are formed termed sinuses, which serve as the venous trunks of the brain; and from their dense unyielding nature are not liable to be dilated like other venous trunks when the return of the blood to the heart is impeded. The smaller veins are further observed in many instances to open into the sinuses obliquely against the natural current of the blood, which when refluent tends to close their apertures, and thus protects them in some degree from its own pressure.

The second or serous membrane of the brain is termed the arachnoïd. It invests the base of the brain and the upper part of the spinal chord very loosely, and even at other parts does not dip into the fissures between their subdivisions. The arachnoïd membrane is reflected to line the inner surface of the dura mater upon the vessels and nerves, which pass from the brain to the dura mater in the cranial cavity and vertebral canal, and in the latter by special additional processes termed ligamenta dentata, which extend from the side of the spinal chord, one between the roots of each nerve, to the theca. The arachnoïd membrane removes the brain from continuous sympathy with the bones and integuments, but it differs from other serous membranes in presenting an unusually dry surface.

The third or inner membrane is the pia mater, or proper tunic of the brain and spinal marrow, which strictly invests the surface, and penetrates throughout the substance of these organs conveying their vessels and determining their fibrous structure. M. Magendie has ascertained that in living animals a quantity of serous exudation always exists between the pia mater and tunica arachnoïdes, which passes readily from the surface of the brain to that of the chord. To see this appearance in human beings it is ordinarily requisite to open the body not many hours after death, or the liquid will have been imbibed by the neighbouring surfaces[a].

The central organs of the nervous system are the medulla spinalis, the medulla oblongata, the cerebrum, and cerebellum. In the following brief description I shall endeavour to define with precision the limits of the medulla oblongata and spinal marrow, and shall, for reasons which will appear in the sequel, include under the former term parts usually considered as belonging to the cerebrum.

1. The spinal chord occupies the theca vertebralis from the first lumbar vertebra, where it terminates in a tapering point, to the margin of the foramen magnum, where it is continuous with the medulla oblongata. The spinal chord has the form of a flattened cylinder: its breadth is greatest at the lower part of the neck and at the lower part of the back: its surface is of white nervous matter. It is marked, 1. anteriorly in the median plane, with a deep longitudinal furrow, at the bottom of which is an appearance of white transverse fibres, resulting from apertures of canals that transmit vessels: 2. behind in the median plane, with a shallow longitudinal furrow: 3. and 4. laterally, with an anterior and a posterior longitudinal furrow on either side, the former irregularly and slightly traced, the latter deeply; the roots of the spinal nerves are attached at these furrows: 5. finally, a third shallow longitudinal furrow is found on either side between the posterior median and posterior lateral furrows. Upon making a transverse section of the medulla spinalis, a thin gibbous layer of

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[a] Journal de Phys. Exper. vol. v. p. 36.

grey matter is seen in either lateral half: the convex margin of each portion looks inwards, and is joined to its fellow by a transverse layer: the anterior horn of the lateral grey matter looks forwards and outwards, and has three points; the posterior horn is prolonged towards the posterior lateral furrow. The surrounding white matter seems composed of thick flattened bands, the thin edges of which are turned towards the grey matter. When the spinal chord has been hardened by continued maceration in alcohol, the white part peels readily into longitudinal fibres, that are resoluble into filaments, which continually branch, and thus attach themselves to those adjoining: the grey matter is of a less coherent texture, and generally appears granular[b].

2. The medulla oblongata commences as a cone about sixteen lines in height, the narrow end of which is of the same breadth as, and continuous in substance with, the spinal chord. Upon either side of and disposed parallel with the anterior median furrow is a broad flattened band called the anterior pyramid, upon the outside of which is an oval prominence, called the corpus olivare. The lateral part of the medulla oblongata is formed of a thick round chord ascending towards the cerebellum, called corpus restiforme or crus cerebelli; and intervening between this and the posterior median furrow is a narrow band termed the posterior pyramid. The posterior pyramid five lines above the commencement of the medulla oblongata forms a knee, and recedes from its fellow, leaving a broad lozen-shaped surface of grey

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[b] The author is preparing for publication a series of engravings, which represent the fibrous structure of the spinal chord and brain.

matter exposed: the surfaces of the rest of the medulla oblongata are white. The posterior median furrow is traced upon the grey matter, and from it on either side a few white filaments extend laterally, to which appearances conjoined the term calamus scriptorius is given. A transverse section of the lower part of the medulla oblongata shows that the horns of the central grey matter enlarge at their extremities, inclosing white matter in an incomplete hollow cylinder of grey. A section through the corpus olivare shows that it contains a thin layer of grey matter very curiously folded so as to be open internally and behind only; it is called the corpus fimbriatum.

The line of separation between the spinal chord and medulla oblongata, though distinct in the recent subject, is more satisfactorily made out in the hardened brain. If the upper part of the anterior median furrow of the medulla oblongata be spread open, the same appearance is met with of transverse fibres as at the bottom of the corresponding furrow in the spinal chord; but towards the lower part three or four broad fasciculi are found to ascend obliquely forwards from the centre of one half of the spinal chord, and to join the anterior pyramid of the opposite side, decussating their fellows. The spinal chord may be described as terminating at the point where this important change of structure first appears. On cutting through the upper part of the anterior pyramid of the hardened brain, it is found to be reticularly fasciculated; and when reflected downwards it appears to be derived, principally by the decussating fibres just described, from the central part of the opposite half of the spinal chord; in part from the anterior fasciculi of the spinal chord on the same side; in part from semicircular fibres that extend to the side of the corpus restiforme, On cutting through and stripping down the corpus restiforme, it is found to carry with it the posterior lateral furrow: the anterior lateral furrow terminates among fasciculi, which are continuous with the corpus olivare.

All the parts of the medulla oblongata, except the anterior pyramids and corpora restiformia, cross over the pons Varolii, and having passed its anterior margin are joined above by a process from the cerebellum, below by the thickened substance of the anterior pyramids, that has passed through the pons Varolii, from the grey matter of which it receives additional filaments. The mass of substance thus formed is termed the crus cerebri: upon its upper part are placed several small hemispherical bodies, of which the tubercula quadrigemina are the most remarkable; they consist of a greyish substance disposed cup within cup, from which fibres are sent to reinforce the crus cerebri: at the same time the crus cerebri is more than half surrounded by the semicircular fasciculi of the optic thalamus: on emerging from thence the greater part of the crus cerebri passes through the grey matter of the corpus striatum, the fore and under part of which affects a disposition in concentric filaments: from each of these bodies numerous fasciculi of white fibrils are added to those of which the crus cerebri previously consisted.

The tubercles, the optic thalami and corpora striata, may be associated with the medulla oblongata in the anatomical description of these parts, upon the grounds, that they continue the function of the medulla oblongata in giving origin to nerves, and that after their abstraction the cerebrum retains all the parts which it ever has in common with the cerebellum.

3. The cerebellum seen from above presents a slanting flattened surface of the breadth of the os occipitis, which would be oval but that its central part is notched before and behind. The surface of the cerebellum is of grey nervous matter, and is disposed in concentric laminæ, separated by furrows from one to eight lines in depth. The under surface is divided into a hemispherical portion on either side, with concentric grey laminæ to each, and the shrunk central portion, separated by a shallow longitudinal furrow from either hemisphere, is transversely laminated: the central portion constitutes the upper and under vermiform processes. The hemispheres of the cerebellum are united anteriorly by a broad band of white matter, called the pons Varolii.

Upon a section of either hemisphere of the cerebellum, the grey matter is seen to form a continuous layer of two lines in depth, spread over white nervous matter, which has the form of a stem dividing into branches which again divide and subdivide. The appearance is termed the arbor vitæ: towards its inner part a corpus fimbriatum is found of larger dimensions but of similar structure to that in the corpus olivare; it is open within and before. The cerebellum is united to the medulla oblongata by its inferior peduncles and by the corpora restiformia, to the brain by the upper peduncles or pillars of the valve of Vieussens. The middle peduncles are those which unite either hemisphere in the pons Varolii.

When the cerebellum has been hardened in alcohol, its white substance is found to be arranged in fibres upon the following plan.

One series of fibres is disposed in plates that are parallel to the surfaces of the laminæ: these fibres are individually disposed in planes vertical or nearly so:

they form media of communication between different parts of the grey surface of the cerebellum, joining together neighbouring laminæ, or laminæ more remote from each other, or finally laminæ belonging to separate lobes.

The central substance of the arbor vitæ is continuous with the peduncles of the cerebellum. The middle peduncle is the largest, is external, and spreads its fibres towards every part of the circumference of the cerebellum. The inferior peduncle is next in size and place, and distributes its fibres in greater proportion to the upper than to the under surface of the cerebellum. The upper peduncle, which is the smallest and innermost, enters the cerebellum covered by the preceding, in great part enters the corpus fimbriatum, and distributes its fibres more to the under than to the upper surface of the cerebellum. On tearing asunder the fibres of either peduncle they are found to be continuous, no doubt through intervals between the former series, with the grey matter of the surface.

The vermiform processes derive their white matter in part from the peduncles of the cerebellum, in part from the Vieussenian valve, which consists of a double series of white fibres, upon the upper surface of which a row of single laminæ is formed of identical structure to those of the upper vermiform process, with which they form a continuous series.

Thus the cerebellum is composed—of a folded layer of grey matter,—of white fibres which connect together the neighbouring and remote folds or laminæ of the same hemisphere,—of white fibres which connect the grey matter of the opposite hemispheres,—of white fibres which connect the grey matter of each hemisphere with the same side of the medulla oblongata,—and of white fibres which connect the grey matter of each hemisphere with the same side of the crus cerebri.

4. The cerebrum seen from above consists of two hemispherical masses, the surface of which is of a grey colour and divided by winding furrows of varying depth from a line to two inches, into the appearance of convolutions. The deepest furrow on the outside separates the anterior from the middle lobe; the deepest upon the inner surface separates the middle from the posterior lobe. The hemispheres cohere by means of a white mass called the commissura magna cerebri: a section of the cerebrum shows that the grey matter forms a layer of the depth of about three lines containing white matter. When the cerebrum is hardened, the grey matter becomes fibrous, and tears vertically to the surface, and the white matter is found to be disposed on the same principle with that of the cerebellum. One series of fibres may be raised in plates which connect the grey matter of adjoining, as well as of distant convolutions of the same hemisphere. Another series collected principally in the corpus callosum and in the anterior commissure connects the convolutions of the opposite hemispheres; and each crus cerebri again spreads its fibres to the convolutions of the whole circumference of its hemisphere. The entire series of white fibres, which, associated with or forming the crus cerebri, diverge from the centre of the base of the brain towards its circumference, are composed, 1. of the anterior pyramid, the filaments of which pass through the intervals of the cross fibres of the pons Varolii, and are reinforced by others, which

distinctly arise from the grey matter contained in these intervals: 2. of all the remaining parts of the medulla oblongata, excepting the corpus restiforme, and part of the posterior pyramid: 3. of the white matter of the valve of Vieussens, and of its pillârs: 4. of filaments derived from the tubercula quadrigemina, from the optic thalamus, from the corpus striatum.

The ventricles of the brain are cavities in it, which in most instances result from the want of adhesion of opposite surfaces of adjoining parts, that have each their covering of pia mater: thus the fourth ventricle is the chamber interposed between the medulla oblongata, the cerebellum, and its peduncles; the third ventricle is the space between the receding surfaces of the thalami nervorum opticorum, and the crura cerebri; and the fifth ventricle is a hollow between the layers of the septum lucidum. In other instances ventricles are cavities wrought in particular organs of the nervous system, not left by the want of union of dissimilar parts in juxta-position. It may be remarked as a law in the formation of the brain, that whenever any part is very strikingly developed, a ventricle is formed in it. The ventricle in the optic tubercle of birds, the ventricle in the processus mammillaris in quadrupeds, the posterior horn of the lateral ventricle in man, a ventricle which exists in the pes hippocampi in man, and the ventricle in the large posterior part of the medulla spinalis in birds, may serve as illustrations of this remark.

The most serviceable impulse that has been given to the study of the anatomy of the brain of late years, we may attribute to the theoretical account given by Drs. Gall and Spurzheim: but the most valuable collection of facts upon the same subject is contained in the essays of Reil. The happiest, and most original observation made by MM. Gall and Spurzheim consisted in pointing out the relation observed in the disposition of the grey and of the white matter in the brain. The examination of the hardened brain by the method of Reil further tends to show that the grey matter in the spinal chord, in the medulla oblongata, in the tubercles, in the corpora striata, and upon the surface of the cerebrum and cerebellum, constitutes the essential part of these organs, or that in which impressions are finally received or with which the phenomena of thought are perhaps immediately connected; while the rest of the mass appears composed of media of transmission only, calculated to convey to one part the influence derived from another.

The nerves in the human body are forty pairs of white chords, in form cylindrical or flattened, which extend from the spinal marrow and medulla oblongata to every organ in the body. The nerves while within the dura mater are either covered with an outer tunic of arachnoïd membrane, or are contained between the arachnoïd membrane and the pia mater. After perforating the dura mater the nerves are invested with a thick dense glistening tunic, which is called their cellular coat. Each nerve consists of many fibrils, that near the brain coalesce by oblique cross branches, and near the circumference of the body lie in parallel apposition only. Each fibril is invested by a delicate vascular membrane, which unites together all the fibrils that are contained within the outer tunic: this membrane is analogous to the pia mater; it forms the proper tunic of a nerve, and is termed the neurilema. Each fibril in a nerve consists of minute filaments, separated or united by layers of the neurilema: the primary filaments are composed of globules resembling those of the brain.

The attachment of a nerve to the brain is termed its root or origin. A large proportion of the filaments that form the roots of nerves may be traced into grey matter. The opposite extremity of a nerve, in the only cases in which the disposition is not too minute for satisfactory examination, terminates in an expansion of grey nervous substance.

Upon some nerves are found oval or spherical swellings of a greyish colour, that are termed ganglia. Ganglia are met with either upon the undivided trunk of a nerve, or where several branches meet. In either case, one series of filaments connects the ganglion with the medulla oblongata or spinal chord, and an opposite series connects it with the organs in which nerves terminate. A ganglion appears to be a bed of gelatinous membrane, within which every nervous fibril that enters it distributes filaments to concur in forming every nervous fibril that leaves the ganglion.

Plexuses are similar interlacements of the fibrils of nerves which are met with in the common cellular membrane of the body, as for instance, in the neck, in the axilla, in the lumbar region, and in the pelvis.

Thirty-one pairs of nerves are derived from the spinal chord by double origins. The anterior roots are composed of numerous fine fibrils which are attached along the anterior lateral furrow: the posterior roots consist of fewer but larger fibrils attached along the posterior lateral furrow. The greater number of the fibrils in the posterior series may be traced to the posterior horn of the grey matter in the same side of the spinal chord; but a portion is continuous with other white matter contained between the posterior lateral and posterior median furrow. The anterior fibrils probably arise in a similar way; but I have never succeeded in tracing them satisfactorily to any distance through the white matter, which I attribute to their minuteness. The anterior and posterior roots are each collected into two fasciculi, and pass outwards, a ligamentum dentatum being interposed between the two, to separate apertures in the theca vertebralis. Upon their emerging from the theca a ganglion is formed upon the posterior root, which immediately afterwards joins the anterior, so as to form with it one nerve. The spinal nerves are named individually after the bone below which they emerge. The uppermost pass nearly transversely outwards, but each in succession afterwards has a greater inclination downwards. The lumbar and sacral nerves fill the theca from the first lumbar vertebra to the lower extremity of the sacrum, and are called the cauda equina.

The nine remaining pair of nerves are termed cerebral, and are named in succession numerically from the fore part to the base of the brain.

The ninth nerve rises by many fibrils from the furrow between the corpus pyramidale and the corpus olivare: these fibrils are generally collected into two fasciculi, which subsequently unite: the larger fibrils may be traced to the surface of the corpus fimbriatum of the olivary body.

The eighth nerve consists of the spinal accessory, the glossopharyngeal nerve, and the nervus vagus. The first rises by many slender filaments from the side of the spinal chord in the upper half of the neck, between the ligamenta dentata and the posterior roots of the cervical nerves. The two last rise by numerous filaments from the fore part of the corpus restiforme: the upper fibrils form the glossopharyngeal, the lower the nervus vagus. All these fibrils may be traced into the substance of the corpus restiforme, with the white filaments of which some of them appear continuous; the greater part tend to the grey matter of the medulla oblongata. A ganglion is formed upon the glossopharyngeal nerve during its exit from the skull, and another upon the nervus vagus at the upper part of the neck.

The seventh nerve consists of the portio dura and of the portio mollis. The former, which is the smaller of the two, rises apparently between the corpus restiforme and the margin of the pons Varolii: its roots are easily followed through the fibrils of the medulla oblongata to the grey matter at its posterior surface. The portio mollis is formed upon the corpus restiforme by two roots; one of which is derived from the same part and in the same manner as the root of the portio dura, the other turning round the outer margin of the corpus restiforme, exhibits a gangliform swelling, and is subsequently found to be continuous with the white fibres of the calamus scriptorius: some of the latter arise from the grey matter, upon which they lie, while others apparently coalesce in the median plane with those of the opposite side.

The sixth nerve consists of two portions, which rise by several fibrils out of the furrow between the posterior margin of the pons Varolii and the anterior pyramid, and may be traced through to the back part of the medulla oblongata.

The fifth nerve emerges from the side of the pons Varolii in a large flattened fasciculus consisting of numerous fibrils, somewhat posterior and internal to a much smaller fasciculus. The fibres of each portion may be readily traced through the pons Varolii, behind which those of the smaller portion pass through the fibres of the medulla oblongata to their origin near its posterior surface. Some of the fibres of the greater portion pass to the same spot, others slant downwards towards the corpus restiforme, internally to which they seem to rise in the medulla oblongata.

The fourth nerve is attached by three or four filaments to the upper part of the pillar of the Vieussenian valve; its fibrils appear to pass through the filaments of the pillar, and in part to rise from the back part of the medulla oblongata, in part to extend through towards the anterior surface of the crus cerebri.

The third nerve rises by many filaments from the black matter behind the outer layer of fibrils in the crus cerebri.

The second nerve rises from the corpus geniculatum internum, from the corpora quadrigemina, from the thalamus nervi optici, by fibrils which form a flattened band under the name of tractus opticus. The tractus opticus swells into an elbow containing grey matter, termed the corpus geniculatum externum, and after a long course joins its fellow at the commissura tractuum opticorum, from which either nerve proceeds through the foramen opticum to the orbit. If the optic nerves, the tractus optici, and their commissure be together hardened in spirit of wine, their fibrous texture readily tears in the following manner. 1. The outer fasciculi at the commencement of the optic nerve are found to be directly continuous with the outer part of the tractus opticus of the same side. 2. The inner fasciculi of the optic nerve, of one side are continued along the anterior margin of the commissure to form the inner fasciculi of the opposite nerve. 3. In a similar manner the inner fasciculi of one tractus opticus are continued along the posterior margin of the commissure, and are reflected to form the inner layer of the opposite tractus. 4. Slender fasciculi are found to run from the tractus opticus of one side to join the nerve of the opposite.

The first nerve rises by three or four roots from the fore and under part of the corpus striatum: upon the lamina cribrosa of the ethmoïd bone it enlarges into an oval body through the addition of grey matter.

SECTION 3.

Of the Parts of the human Nervous System necessary to Sensation, Instinct, and Volition.

1. It may be presumed that those portions of the human nervous system are sufficient for sensation, volition, and the commonest instincts, which correspond anatomically with the entire nervous system of invertebral animals. Now the nervous system of articulated animals (and that of radiated animals on the one hand, and of mollusca on the other is not essentially different) consists of a double chord, from definite points upon the whole length of which nerves are derived to the parts adjacent. But the medulla oblongata and spinal chord in man admit of being described in precisely the same terms. It follows therefore by analogy that these parts are likely to be the organs connected with those moral

phenomena, which are shared by animals from a star-fish to man inclusively.

The following account by Mr. Lawrence of an acephalous infant, which lived four days, establishes the soundness of this conclusion.

"The brain and cranium were deficient, and the basis of the latter was covered by the common integuments, except over the foramen magnum, where there existed a soft tumor about equal in size to the end of the thumb. The smooth membrane covering this was connected at its circumference to the skin. The child, as is generally the case in such instances, was perfectly formed in all its other parts, and had attained its full size. It moved briskly at first, but remained quiet afterwards, except when the tumor was pressed, which occasioned general convulsions. It breathed naturally, and was not observed to be deficient in warmth until its powers declined. From a fear of alarming the mother no attempt was made to see whether it would take the breast: a little food was given it by the hand. It voided urine twice in the first day, and once a day afterwards. It had three dark-coloured evacuations. The medulla spinalis was found to be continued for about an inch above the foramen magnum, swelling out into a small bulb, which formed the soft tumor upon the basis of the skull. All the nerves from the fifth to the ninth were connected with this. The intestines contained a moderate quantity of the usual dark-coloured substance; and there was a little fluid of the ordinary appearance in the gall-bladder [b]."

It is satisfactory to find that the results of experiments upon living animals are in complete agreement with the remarkable phenomena of the preceding case.

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[b] Medical and Chirurgical Transactions, vol. v. p. 169.

M. Magendie mentions that if after the removal of the upper part of the cranium in a living animal, the cerebrum, the optic tubercles, and the cerebellum be removed in successive slices, leaving the medulla oblongata entire to above the apparent origin of the fifth pair of nerves, the animal is rendered blind, but continues to be affected in as lively a manner by pungent odours or tastes, or by irritation of the skin, as if no further injury had been sustained than the loss of blood occasioned by the experiment. The animal cries, if a hair of its whisker be plucked, or if vinegar be held to the nose, and strives with its fore feet to rid itself of the object which incommodes it: the movements of the body are not more affected than if the cerebellum alone had been removed. These phenomena may be observed to continue for more than two hours, when the experiment is performed upon an adult hedgehog[c].

2. It appears that each segment of the body of an invertebral animal has a corresponding segment of the nervous system appropriated to it,—a nodule namely, or pair of nodules, with the nerves thence derived. A very similar disposition of parts may be observed in the human nervous system; and serves to elucidate the following incidents noticed in experiments upon vertebral animals. If in a rabbit the spinal chord be divided both at the foramen magnum and in the middle of the back, on touching the surface of the eye the eyelids are instantly

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[c] Anatomie des Syst. Nerv. &c. par F. Magendie et A. Desmoulins. p. 560.

closed; upon pinching the fore foot, the fore leg is drawn up; upon pinching the hind foot, the hind leg shrinks from the injury. If the head of a pigeon be cut off, and the upper part of the cranium be instantly removed with a sharp instrument, and the cerebrum be removed by a horizontal section at the level of the tubercles, and the cerebellum and medulla oblongata, by a vertical section at the posterior margin of the tubercles, and the second and fourth nerves be divided,—leaving a segment of the brain connected with the eyeball by the third nerve only, —on pinching the end of the optic nerve attached to the segment of the brain, the pupil is suddenly contracted. From these instances we may infer that each segment of the spinal chord and medulla oblongata, with the nerves derived from it, contains the physical organization requisite for sensation and instinctive action. We observe that an impression being made upon an organ of sense, a change is produced in an isolated portion of the central organ of the nervous system, which is followed by the transmission of an irritation to voluntary muscles.

3. The chords which unite the nodules in the nervous systems of invertebral animals we may presume are intended to transmit reciprocally the influence of the different segments of the nervous system from one to another. The white fibrous strings, which form the outside of the spinal chord in man and vertebral animals, have probably the same office. In the experiment upon a rabbit above described, the division of the spinal chord in two places produced three independent centres in the nervous system. If in a snake the head alone be removed, upon wounding the middle of the body the neck is raised and bent towards the point at which the injury is inflicted.

4. In some of the invertebral animals either extremity of the central organ of the nervous system seems to have an equal and independent influence: if a millepede be divided, either half re-produces what is wanting, and becomes a sentient being. But in the scale of improvement in proportion as the nodules on the nervous system accumulate towards the head, this part assumes a predominating influence over the rest. It appears, however, by what has been already mentioned, that warm-blooded animals survive for a period the removal of the cerebrum and cerebellum, if that part of the medulla oblongata be left entire, to which the fifth and seventh and eighth nerves are attached. In reptiles life endures much longer under these circumstances: a frog preserves its vitality for a considerable time after a similar injury: its muscles act in concert, and the animal when left at rest may be observed to draw up its legs, and to sit in its common attitude. But if the medulla oblongata be then removed, the spinal chord and the nerves of the body and extremities being left uninjured, the animal instantly lies relaxed and nerveless. Its foot indeed will still for a short time continue to be retracted when pinched, but the co-operation of all its parts in a sustained effort is lost, and the animal dies. The same happens if the brain be previously entire; and occurs equally or in a more striking manner in warm-blooded animals. A slighter injury of the medulla oblongata produces a corresponding result; pressure upon it causes stupor; and half the dose of alcohol otherwise necessary produces a like effect, which is removed by the exhibition of prussic acid. In human beings we have every reason to attach an equal degree of importance to the medulla oblongata,

and we may suppose its mechanical continuity with the parts adjoining necessary to their function.

5. But the medulla oblongata has another important object, that of reciprocally transmitting the influence of the brain and spinal chord from the one to the other; and the most satisfactory observations respecting the dependence of the functions of the latter upon its continuity with the medulla oblongata are deducible from instances in which the brain has been left entire. One of these I have just mentioned.

M. Magendie ascertained that on the division of the posterior or upper half of the spinal chord, the sensation of the parts supplied with nerves from the caudal extremity of the spinal marrow is lost, while voluntary motion remains: and on the other hand, that the division of the anterior or under portion interferes with voluntary motion, but leaves sensation unaffected. It is remarkable that the posterior portion of the spinal chord, which appears the medium through which sensation travels, is itself highly sensible, while the anterior portion has scarcely any sensibility. Upon minutely examining this point, I observed that the portion of the spinal chord contained between the posterior lateral furrow and the posterior median furrow is alone acutely sensible. M. Magendie found that upon destroying with a wire the central part of the spinal chord, sensation and voluntary motion are not interrupted.

When the spinal chord is divided in experiments upon warm-blooded animals, or by accidental injury in human beings, or is compressed or lacerated, the lower part of the body is totally paralysed. This result is so uniform, that we are bound to suppose an error in the narrative of two well attested cases on record of sensation and voluntary motion continuing after the division of the spinal marrow. Some violence is scarcely avoidable in opening the vertebral canal; and if the spinal chord be already partially divided, the operation of exposing it may easily complete the rupture. How slight a continuity of nervous fibre is sufficient to sustain the communication between parts of the medulla spinalis, must be known to those who have attempted to destroy animals by pithing; a very slender layer of nervous substance will enable the animal to continue breathing, which, however, ceases instantly on its division. The following case is to the same purpose.

A person died at the age of forty-four, seven years after having lost the use of his arms, which had become painfully contracted although preserving their sensibility. The lower part of his body had in no degree participated in the same affection: he had been to the last violently addicted to sexual indulgence. Upon dissection the spinal chord at the lower part of the neck, and upper part of the back, was found converted into a colourless diffluent substance containing flakes of nervous matter, all but two narrow bands, one in the line of each anterior lateral furrow, which appeared of their natural texture, and joined the sound inferior portion of the spinal chord to the upper part[d].

6. As it appears that different parts of the spinal chord are connected with sensation and volition, we are naturally led to inquire, whether a similar distinction holds between the different nerves which rise from it

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[d] Magendie. Journ. de Phys. Exper. tome iv.

and from the medulla oblongata. We may presume that this is the case from various instances in which parts, that both enjoy a special sense and are endowed with muscular action, are supplied with several nerves from different sources. Thus three nerves are distributed to the tongue, and five in the orbit. My own experiments again upon the functions of the 5th and 7th nerves, and those of M. Magendie upon the roots of the spinal nerves, have proved that in almost every case sensation and volition are connected with different nervous fibrils.

The muscles and integuments of the face are supplied with branches from the portion of the fifth nerve which traverses the ganglion of Meckel, and with branches of the portio dura of the seventh. Upon dividing the branches of the fifth upon the face of an ass, sensation was observed to be lost: but although it seemed at first that the muscles of the face were besides partially paralysed, yet upon a more attentive examination it became evident that the power of voluntary motion remained perfect; the nostrils were dilated at each inspiration, the lips continued to be held in some degree of apposition and with something of their natural expression, and were more than once retracted so as to uncase the teeth in efforts which the animal made to bite. The lips were indeed no longer used in the prehension of food;—a curious phenomenon, but sufficiently explained by the loss of sensation in these parts. The ass habitually is guided in the prehension of food by the sensation with which it affects the lips: the lips are so placed that the eye cannot be directed to the objects which they touch: the animal was observed in the experiment described to strain its vision towards the object to which its lips were approached; but when they came in contact with the proffered food, there was no sense to direct their further action. The immediate dependence of voluntary action upon sensation is remarkably illustrated in Anæsthesia. This affection consists of the loss of sensibility in a part, the muscular power remaining: it is commonly met with in the hands and fore-arms. A person afflicted with it can employ the hands to support a weight as long as the eye is directed towards the object; but if the attention be for an instant diverted and the eye turned elsewhere, the weight escapes his grasp[e].

Upon dividing the trunk of the portio dura on each side of the face of an ass, the sensibility of the face remained unimpaired, but the muscles of the face were entirely paralysed, the eyelids remained open, the nostrils motionless, the lips relaxed, falling away by their own weight from the teeth.

Upon pinching the branches of the fifth nerve immediately after death, no action follows in the cutaneous muscles to which they are distributed; upon pinching the trunk of the seventh, a sudden action ensues of all the muscles of the face.

Upon subsequently dividing the fifth nerve in the cranial cavity of a pigeon, I found that the surface of the eye lost its sensibility by this experiment, while the motion of the iris remained unaffected; and I afterwards established that the muscles of the lower jaw, which receive branches from the fifth exclusively, derive their supply from two sources, the portion of the fifth, namely, which traverses the ganglion of Meckel, and the smaller portion which passes below it, and is consumed upon this object; and as the former are upon analogy proved to be nerves of sensation, it follows that the latter are nerves of voluntary motion. Thus is explained the seeming intricacy which exists in the distribution of the facial nerves, and the position greatly confirmed that sensation and volition are connected with different nervous fibrils.

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[e] Medico-Chir. Trans. vol. i.

The remarkable analogy, which exists between the fifth nerve and the spinal nerves, led me to suppose that the two roots of the spinal nerves had the same discrepancy of function with the two roots of the fifth; and that the ganglionic portion might belong to sensation, the smaller anterior portion to volition.

The well-devised experiments of M. Magendie in the mean time determined this opinion to be correct: upon dividing the posterior roots of the spinal nerves, sensation was found to be lost: on dividing the anterior roots, voluntary motion ceased in the parts supplied by the mutilated nerves.

But when thus sharing the claim to these discoveries between M. Magendie and myself, I should in justice state that the experiments in each case were but improvements upon those which Mr. Bell had previously performed. Mr. Bell's ingenious Essays upon the nerves are well known to every one; and besides the valuable facts which they contain, they have the merit which belongs to originality, even when only partially successful in eliciting truth.

7. It remains to inquire, whether the nerves in contributing to sensation and volition serve merely as conductors to transmit impressions, or in part originate the

influences which they convey. The first supposition, though far from proved, appears the most plausible. The length of a nerve does not seem to affect its function. When a nerve is divided, whether near its origin or its termination, its function beyond the point of division appears equally and entirely lost, as far as regards consciousness. After the amputation of a limb, it not unfrequently happens that sensations are experienced as if the limb were perfect, and that pain is distinctly referred to the point of space, which in the shifting position of the body the limb if not removed would occupy. M. Fodera found that on exposing the spinal marrow in an animal, to which strychnine had been given, he could arrest the convulsions of any part by making pressure upon the segment of the spinal chord, which gave origin to the nerves that supplied it.

SECTION 4.

Of the Functions of the Brain.

The human mind, wakened into active existence by sensation, exhibits the instant after birth simultaneous evidence of instinct and volition, and upon the gradual excitement of its dormant faculties may figuratively be said to grow by the addition of moral elements. The mind has its moral parts, as the body its physical, its various active principles and intellectual powers.

The mind appears to consist of a succession of moral changes. Whatever affection has once occurred has a spontaneous tendency to recur, though with diminished intensity: thus even the conception of a former object of sense may approach in vividness under favourable circumstances to actual perception. The tendency of the mind to recall past impressions is termed the association of ideas. It seems that every assignable relation between ideas may serve to connect them, so that the one may suggest the other.

In the train of thought, if one particular image strongly excite the mind, it remains for a period without an effort the principal object of contemplation: yet the succession of ideas is not arrested, but seems to proceed in part unheeded, exciting our attention only when its suggestions illustrate or bear upon the leading object of our thoughts. In like manner by an effort of attention we are capable of selecting any idea, which casually presents itself, and of fixing it steadily before the mind, or of continually reverting to it, so as to compare with it all the elements in the current of thought, that it may combine with those with which it may have an affinity. By a ready memory we bring quickly, by a retentive memory we are able to bring from a long experience, former impressions that bear upon a point of consideration.

The habits of one mind are to collect, to hoard, to arrange the results of experience; of another, the habit of association is inventive, or delights in viewing under new combinations the elements of acquired knowledge.

A subject that occupies the mind is submitted, as habit or inclination may direct, to the agency of distinct and simple faculties, which judge whether a proposition or a sentiment be true, or ludicrous, or sublime, as the external senses decide upon an object of sense, whether it be coloured, or sonorous, be hard, or fragrant. And as the eye directed over an extensive prospect sees at the same instant but one point, yet is capable of forming or furnishing a full and vivid conception of the whole, so the mind though immediately conscious at one and the same instant of one affection only, yet has a comprehension adequate to receive the collective impression of many. As the mind at one time is ardent, at another desponds, its judgment is liable to be frequently clouded or perverted, those considerations having disproportionate weight which accord with the prevailing tone of feeling.

All men possess certain common tendencies. All men in common derive pleasure from some impressions and are painfully affected by others: upon this principle, joined to a calculation of their expediency, different nations have agreed in condemning certain actions and approving others; and the progress of philosophy and the light of Religion have finally concurred in establishing general rules that are applicable to every question of human conduct. Children act upon first impulses; men, after weighing the consequences of their actions. What is termed our free will is founded upon the power which we possess of representing beforehand to the mind the consequences of our actions. The wise cultivation of the mind consists in accustoming the understanding to discriminate accurately truth from falsehood, and in training our inclinations to follow habitually the guidance of reason.

To trace the assemblage of phenomena which constitute a mind to their first principles, is the province of metaphysics: to show with what material conditions their manifestation is connected, is a part of physiology. And as on the one hand just views in metaphysics are essential to perfecting this part of physiology, so on the other are requisite, 1. a complete anatomy of the human brain calculated to show the connexions of its different parts, or the material channels by which their influence is reciprocally propagated: 2. a comparison of the human brain with the brains of animals which exhibit remarkable diversities in their moral features: 3. an account of the results of experiments in which parts of the brain have been removed in animals: 4. an account of human monsters where part of the brain has been originally defective: and 5. an account of cases where from disease or injury different parts of the human brain have been destroyed or their connexion interrupted. Something in furtherance of this extensive plan has been done already: it may be observed, that the elementary problem to be solved is the structure of the human brain, which may indeed itself be partially elucidated in the progress of experimental inquiry, but which must be carefully unfolded by direct anatomical research, before experiments or pathological observations can be conducted with sufficient precision to render their results conclusive.

At the beginning of the seventeenth century Harvey laid the foundation of modern physiology by his unrivalled discovery of the circulation of the blood. Aselli soon after discovered the existence and the use of the lacteals; and in the middle and latter part of the eighteenth century, the labours of Haller, of the Hunters and of their school, contributed mainly to complete our present knowledge of the vital œconomy as far as regards the phenomena of nutrition, and showed that its springs and sources are to be found in the observation of the organized frame, not deduced from physics or chemistry.

But as yet little was known of the influence of the brain and nerves: experimental inquiries into the functions of the nervous system are the distinguishing feature of the physiology of the nineteenth century. Le Gallois, Philip; Home, Brodie and Magendie; Bell, Fleurens and Rolando, take the first place among those whose distinguished researches have been confined to or have included the elucidation of this important subject. In determining the influence of the cerebral masses, Rolando and Fleurens, Magendie and Fodera, have been the most successful. The facts they have brought to light are in the highest degree curious; and at the same time that they show how remote we are at present from a knowledge of the functions of the brain, they yet hold out a fair prospect of the ultimate result of uniting anatomy with experimental physiology and pathological dissection upon the present object of inquiry.

In serpents the cerebellum is wanting: in fish it forms a diminutive part of the brain, and its removal produces no further effect than that of apparently weakening the animal: frogs, from which this organ is removed, show an indisposition to move unless irritated or placed in water, when their movements, though less lively than before, are not observed to be otherwise affected.

In birds and mammalia more important results ensue upon the injury or removal of the cerebellum, which it may be remarked appears not to be sensible to pain from mechanical lesion.

If the cerebellum be wounded upon one side, the animal appears to be generally weakened upon the same side: if the wound be deep, the body upon the injured side is rendered paralytic. If in a rabbit the upper and middle portion of the cerebellum be removed, the hind legs are observed to be spread, the fore legs are extended forward in a state of rigidity: the whole attitude is that of preparation for moving backwards or throwing itself over. After a short time the animal beats the ground with its fore paws, the hind legs not moving, and urges itself backwards. If the tail be pinched, the animal thus excited still moves its fore legs only, and continues moving backwards. A deeper incision causes the animal to fall upon its side, the head is drawn backwards in a state of tension, the feet, and especially the fore feet, which preserve their rigid extension, are moved with violence.

The flight and the walk of pigeons are not affected by the removal of the upper part of the cerebellum. After a deeper section has been made, the bird totters, falls on its breast, rises again, and is in continual agitation. A deeper section still causes it to walk and to fly backwards. After the entire removal of the cerebellum the bird when irritated walks almost as usual; when thrown into the air, it moves its wings regularly, and alights upon its feet. A few minutes afterwards the legs become rigid, but the wings still move regularly if the bird be again thrown into the air: the legs remain in a state of tension, and the head continues drawn backwards till death. M. Fodera saw all these phenomena succeed each other in the same bird, but each may be immediately produced by the fit incision. M. Magendie mentions the case of a young woman, who is affected with a nervous malady that forces her to run rapidly backwards, disregarding every peril.

The simplest explanation of the phenomena above described, is to suppose that an injury of the cerebellum to a certain depth produces a sensation analogous to vertigo; that the animal conceives itself either to be hurried forward, and makes a more or less perfect exertion to repel the imaginary force, or to be moving backward, and moves its limbs to a certain degree in correspondence. Either of these suppositions, which rest upon analogy, appear more likely to be just than the hypothesis that an animal exists under the influence of two impulses, one urging it forward, the other backward, and that the organ of one impulse is removed on the partial destruction of the cerebellum.

M. Fodera found similar phenomena to be produced upon the injection of a solution of camphor in oil into the abdomen in animals, either before or after the removal of the cerebrum, and remarked that they became more intense on removing a part of the cerebellum.

Lateral pressure of the cerebellum produces no effect that has been observed.

M. Magendie found results not less unexpected ensue upon a vertical division of the cerebellum, the crura cerebelli, and the pons Varolii.

If in a rabbit a section of the middle portion of the cerebellum be made in the median plane, the eyes of the animal are observed to be in extraordinary agitation, and as if starting from their sockets: the animal inclines towards one side, then is suddenly thrown towards the opposite, as if unable to balance itself with precision: its fore legs are rigidly extended forwards, as if it were in the act of receding.

If a vertical section of the cerebellum be made, leaving ¼ of the whole adhering to the crus of the right side, and ¾ to the left, the animal rolls over and over incessantly, turning itself towards the injured side. The right eye is directed downward and forward, the left eye upward and backward. On making a similar section upon the left side the animal stops, and the eyes resume their natural direction.

M. Magendie was led to this discovery by accidentally dividing the crus cerebelli in a rabbit, upon which the same phenomenon occurs as upon dividing the cerebellum unequally. For eight days that this animal survived the injury, it continued to revolve upon its long axis unless stopped by coming in contact with an obstacle: when stopped, it ate upon its back with its mouth upwards. If the opposite crus be subsequently divided, the movement produced by the first experiment is stopped.

If the cerebellum be divided unequally, so as to produce a constant revolution towards the mutilated side, and the opposite crus cerebelli be subsequently cut through, an equilibrium is not produced, but the animal begins to revolve towards the side on which the crus is divided.

The whole of these phenomena are probably attributable to a sensation analogous to vertigo: this conjecture at least appears strongly confirmed by the following case described by M. Serres.

A shoemaker sixty-eight years of age, of intemperate habits, after a debauch exhibited a kind of drunkenness, which surprised his friends: instead of seeing objects turn around him, he seemed to himself to be turning, and in a few moments commenced revolving; placed in bed he continued to manifest this tendency till he died. Upon examining the head an extensive lesion was found of one of the peduncles of the cerebellum.

The tubercles placed between the cerebellum and the cerebrum, in part give origin to the optic nerves, in part send fibrils to the cerebrum.

On injuring the optic tubercle of one side in pigeons, blindness ensues of the opposite eye; and reciprocally on dividing one optic nerve, the under surface of the opposite tubercle to which the nerve adheres is found to become wasted in a few weeks.

On injuring deeply the optic tubercle in birds and mammalia, when the greater part of the brain especially its base has been left entire, the animal in flight or in its walk moves continually round towards the same side. In serpents and frogs the movement thus produced is towards the opposite side.

Pain and convulsive movements are produced by wounding this part of the brain.

If the cerebrum be removed in frogs and fish, their movements are seemingly as spontaneous as before.

If the upper part of the cerebrum be removed in birds and mammalia, the animal becomes blind and appears stupefied; but when excited, locomotion is performed with steadiness and precision, the animal walks when pushed, or if a bird, flies when thrown into the air. No further result is produced by the additional removal of the grey matter of the corpus striatum; but if a section be carried through the striated part, the animal springs forward, and continues to advance in a straight line till it meets an obstacle, when it still preserves the attitude of one advancing. This result ensues when the experiment is performed upon dogs, cats, rabbits, Guinea pigs, hedgehogs, and squirrels: the latter only in advancing cross their fore legs as in the action of climbing a branch, and if a stick be placed in their embrace, they ascend it.

Upon making lateral pressure on the hemispheres of the brain, no effect has been observed to ensue. Upon making vertical pressure upon the brain stupor takes place, which is attributable to the compression of the medulla oblongata. It deserves remark that when vomiting has been excited by an emetic substance, it is arrested by pressure made upon the medulla oblongata.

The water contained between the tunica arachnoïdes and pia mater appears intended to produce an equable pressure upon the entire surface of the brain and spinal chord. M. Magendie discovered that when this equable pressure is suddenly taken off by letting out the water, the functions of the organ are commonly but not invariably suspended; its gradual diminution produces no effect.

Reil describes his having examined the head of an idiot thirty years of age, who had been employed in the little traffic of neighbouring villages, in whom the middle part of the corpus callosum was entirely wanting from an original malformation, as it seemed; for the convolutions were complete where a corpus callosum ought to have joined the inner surface of the hemispheres.

Finally it may be observed, that in human beings an injury upon one side of the brain almost constantly produces palsy of the opposite side of the body, which is frequently attended with a paralytic affection of the face upon the injured side. It is impossible not to suppose this phenomenon connected with the decussation of the anterior pyramids, by means of which each lobe of each hemisphere of the brain is rendered continuous with the axis of the opposite half of the spinal chord. Yet in the experiments of M. Magendie it was found that division of the anterior pyramids, one or both, in animals produced no further effect than a slight impediment in their movements forward; and that division of the entire half of the medulla oblongata produced palsy of the same side of the body.

The experiments which have been described, curious and interesting as they are, throw indeed little light upon the connexion of the brain with the higher qualities of the mind; and our vague and imperfect conclusions upon this question rest at present upon other grounds.

Of all the parts of the nervous system, lesion of the brain alone has been observed to affect directly the faculties of the mind; and in man the cerebrum and cerebellum have an amplitude and complexity of structure, which conjointly much exceed the same qualities in the brains of animals. It seems not indeed that the brute volume of the whole or of any portion of the brain has reference to the vigour or energy of the faculties of the mind. A mask of Newton is in existence, and it shows no unusual breadth or height, or remarkable partial development of the forehead: the masks of Chatham and of Pitt have the same feature low and narrow; and it must consist with the observation of every one that the broadest and most ample fronts among his acquaintance far from commonly belong to men of the most acute or powerful minds. Yet it seems that there is some physical relation between the composition of equal masses of the brain and the quality of the mind, that has energized by their intervention. M. Magendie ascertained that in persons above the age of seventy, the specific gravity of the brain is less on an average by a fifteenth, than in adults; and further remarks, that a general proportion exists between the number and depth of the convolutions and laminæ upon the brains in animals, and the development of their moral endowments. In birds in which vision is extremely acute, the grey matter of the retina lies in numerous folds: the grey matter of the brain we have already seen reason to believe the part in which its functions originate; and no difference is more striking in the examination of human brains, than the varying number and depth of the convolutions upon the same extent of surface. Thus analogy finds in a common difference among brains a physical cause, that may essentially modify the phenomena of consciousness. It remains to accumulate histories of remarkable diversities of character in connexion with the appearances observed on a careful examination of the form and structure of the brain: and it is far from improbable that each class of moral phenomena will be found to be separately associated with a distinct part of the brain, according to the theory of Gall, whose inquiries have hitherto proved as unsuccessful, as in their conception they were philosophical.

SECTION 5.

Of Sleep, Dreaming, and Sensorial Illusions.

The period of a diurnal revolution is shared between sleeping and waking: during six or eight hours of the twenty-four, consciousness appears suspended. After a day spent in active exercise, the limbs feel fatigued, the mind is less lively and less capable of continued attention, the senses become duller, we seek to dispose the body in a posture requiring the least muscular effort to sustain it, we withdraw the mind from reflections calculated to excite its powers, we seek to close the avenues of sensation, the images before the mind become more and more faint, and by insensible gradations we become unconscious.

During sleep the circulation is more gentle, the respirations are less frequent and are deeper, the temperature is lowered, the cutaneous transpiration is increased. The sleeper perhaps remains for many hours without motion, undisturbed by the loudest sounds or the brightest light.

If a sleeping person be awakened by opening the eyelids under a strong light, the pupil for the first second or two is seen to be extraordinarily contracted, which we may presume to be its usual state during sleep: the pupil then becomes widely dilated, but again contracts and dilates before it becomes steady: at the same time the person moves himself, articulates unconnectedly, and seems endeavouring to collect his scattered thoughts. The mind quickly recovers its wonted character, the memory of the events of the preceding day returns, but with it in most cases no recollection presents itself of a state of consciousness between the period of falling asleep and that of waking.

Among the instances in which the memory retains no evidence of the existence of consciousness during sleep, some are nevertheless attended with phenomena, which distinctly show that consciousness has not been entirely suspended: for, that I may not mention breathing as an evidence of voluntary motion (it being no doubt disputable whether each act of inspiration be voluntary or proceed from an automatic influence), a person asleep will sometimes turn his head from the light, or shift the position of a limb or of the body when it is reasonable to suppose that it has become inconvenient: many animals likewise sleep in postures in which they cannot be sustained without the measured employment of voluntary muscles. Among many other facts of common observation, none perhaps is more conclusive than the estimate which seems to be made of the flight of time during sleep, so that a person anxiously bent upon awaking for an important object at a definite hour, will be sure against his usual habits, and in defiance even of accidental fatigue, to wake before the hour required.

There are other instances in which the memory retains the clearest impression of various affections of consciousness having taken place during sleep. In dreams, the images presented to the mind are sometimes incoherent and disjointed fragments of events: at other times the train of imaginary circumstances is connected, and capable of producing an interest as intense as reality. Sometimes the mind is in its finest mood of invention. The musician and the poet have been known to regret, upon waking, their imperfect remembrance of what seemed the brightest gems of their fancy. Sometimes a dream is but the imaginary continuation of trifling or important engagements of the preceding day; at other times it shapes itself to the present impressions upon the senses, and a sound imperfectly heard, a light flashing upon the closed eyelids, suggests to the imagination a rapid train of correspondent images, of which it forms a part. At the moment of waking, dreams are often freshly remembered, which quickly fade from the recollection: at other times some accidental association brings distinctly before us the events of a dream, which till that moment had never been remembered; leaving it uncertain how frequently the mind may thus energize, though its impressions associated with no object of sense may often fail of being brought back to the mind in its waking state.

The mind in ordinary dreaming moves in its accustomed channels, without an effort being made to interrupt or modify the train of its spontaneous associations. The character might therefore be elucidated by a history of the dreams of an individual; nor is it more wonderful that their suggestions should sometimes be prophetic, than that a rational judgment should frequently be able to foresee the probable occurrence of events, or that in the varied combinations of hazard a wild suggestion of the waking fancy should sometimes be realized. A lady, whom I have the pleasure of knowing intimately, was requested to purchase a particular ticket in the lottery by a friend resident abroad, who found herself so haunted by the number 10,000, that when she wrote, her hand unintentionally formed these figures. The ticket was bought, and was drawn a 20,000*l.* prize: the same figures might have occurred to the mind in a dream shaped in a prophetic character.

But the phenomena of dreaming are not always confined to the spontaneous suggestions of the fancy; occasionally the mind seems to bend itself during sleep to an examination of the impressions which occupy it. It has happened that a person has doubted during a dream the reality of the circumstances in which he imagined himself placed, and after a process of deliberate reflection has become satisfied that he was awake.

A curious if not a conclusive argument against the theory of materialism may be deduced from the phenomena of dreams. The images in a dream are for the time believed to be as real, as those presented by the senses during waking existence: and we distinguish the one from the other by the consistency of our waking impressions, contrasted with the incoherency of our dreams. Thus a person who has fallen into a dream which continues the adventures of the preceding day, is at a loss for a few seconds upon waking, as to where reality ends, and where his recollections are patched with what is visionary. On the other hand, a person suddenly finding himself under circumstances totally contrary to probability and expectation,—one for instance who having sat out his companions at a tavern in the midst of a large metropolis, should rise and see instead of glimmering lights and dingy buildings a yawning gulf spread immeasurably before him; such a person would doubt his being awake, and for some time probably would be unable to satisfy himself whether he saw a real object, or slept and dreamed.

Thus it appears that our conviction of the existence of surrounding objects, when awake, does not in truth result from an intuitive belief produced by sensation, but is founded upon a theoretical view of the phenomena of consciousness: in sensation the mind may *possibly* not be wrought on by physical agents: however unlikely the supposition may be, it is yet *not impossible* that the current of our waking impressions may be analogous to those of a dream: that, for instance, the will of the Creator may immediately cause those successive affections of the mind, which we interpret as evidences of a material world.

It is not my object in the present argument to support the theory of Immaterialism, and to attempt to prove that matter has no existence independently of our sensations: common sense and the practical belief of every one concur in establishing the enormous probability that history and science are not a dream. I am desirous only of illustrating the nature of the evidence upon which we believe in the existence of matter. The best, but not the only mode we possess of explaining the impressions which we receive from sensation, is to suppose the existence of a material world, and of beings like ourselves. But the evidence of the existence of mind is intuitive; a sceptic cannot even doubt without admitting that his doubt constitutes an affection of an immaterial substance. Yet will he venture to attribute the production of mind, *of the existence of which he has intuitive evidence*, to the influence of material structure, *his belief in the existence of which rests but upon a theoretical explanation of certain phenomena of consciousness.*

An eminent metaphysician has supported the opinion that in sleep "the will loses its influence over those faculties of the mind, and those members of the body, which during our waking hours are subjected to its authority[f]." In the remarks which I have made upon the phenomena of consciousness, I have employed the term will to signify exclusively that affection of the mind, which is the immediate cause of muscular action: that *this* influence is not in every case suspended during sleep, appears evident upon the fact already adverted to, that many animals sleep in postures which require a sustained muscular effort. But we seem to exercise a voluntary power likewise over the affections of the mind: let us examine, before resuming the preceding inquiry, whether the latter influence be suspended during sleep. The faculty by which we direct the mind at pleasure to one train or mode of thought or to another, is essentially unlike that, by which we produce a series of voluntary movements. Under ordinary circumstances we are indeed equally led to either,—to analyse for instance an affection of consciousness, or to strip the shell from a filbert,—by the gratification it promises: but while in the one case the effect we desire is attained directly and instantaneously,—we will and the muscles act,—in the former the effort consists in fixing the attention upon a subject of inquiry, and patiently observing the bearing of every thought, which presents itself, upon the point before us. In producing a muscular effort, we will a physical change, and it instantly ensues; in an effort of thought, we but confine the mind to a definite track, expecting that our established habits of association will bring us to the conclusion we wish.

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[f] Stewart's Philosophy, vol. i. p. 330.

Now it appears from an instance of dreaming already mentioned, that the mind can during sleep set on foot an analytical inquiry, and may compare its different impressions in order to arrive at a conclusion respecting their nature,—an operation as voluntary, if the expression be applicable, as any which the mind exhibits in its waking state.

Mr. Stewart supposes that the phenomena of nightmare or incubus illustrate the suspension of the influence of the will during sleep. The patient appears to himself to experience uneasy sensations, produced perhaps in part by the accidental posture of his body, which he finds it impossible to remove by his own efforts, and he feels distinctly conscious of an incapacity to move: or in a case perfectly analogous he imagines himself pursued during a painful dream, and attempts to fly, and his legs seem to refuse to perform their office. But it appears questionable whether in these instances the supposed effort of the will really take place. The person is not conscious of his real position, (if he were he would be awake,) and makes no effort to change *that*. He may possibly be suffering an uneasy sensation, but it is not presented in its true form to the mind; it is wrought up in all the horrors of a dream, and the attempts to escape from the load are in their nature fictions as well as the sufferings which suggest them. A person wide-awake will occasionally give the reins to his fancy, and frame before his mind scenes of the most exciting description, in which he supposes himself to play a busy part, interfering to save by a vast display of strength and activity, or indulging perhaps in the happiest flow of eloquence, in keen and pointed reply to imaginary invective, the very tone of which is supposed to add to its poignancy; but not a muscle does he move, although the scene in which he is engaged has an interest almost equal with reality. In a troublesome dream the case is similar; but the patient is essentially lost to every thing external, and having no means of detecting their unreal nature, is wholly absorbed in the creations of his fancy, to which alone his anxiety and his fears have reference. He wishes not to jump out of bed, but to escape the grinning jaws of the monster that threatens him. He is uneasy and oppressed, but there is no real load to be thrown off.

Perhaps it would be more just to say that the influence of the will over the voluntary muscles during sleep, instead of being suspended, appears rather not to be habitually exerted; unless indeed breathing be voluntary. But there are some persons who talk during their sleep, as absent persons sometimes indulge themselves in making remarks aloud, or in gestures, which have reference to the reverie in which they are engaged. The phenomena of somnambulism likewise, although very imperfectly understood, concur with the preceding instance in distinctly proving the exertion and influence of the will during a modification of sleep. In many cases of this affection it appears that the main action conducted has reference to a dream, while the somnambulist, though little conscious of surrounding objects, yet appears in part to be guided by sensation in his voluntary efforts.

In perfect health the impressions of a dream or reverie are instantly dispelled, when compared with actual sensation. But when the nervous system is disordered, the creations of the fancy sometimes appear mingled among real objects, and assume an illusive existence in the external world of persons thus affected. To illustrate at once and to exhaust this subject, I extract from Dr. Hibbert's interesting volume upon the philosophy of apparitions the account given by Nicolai of his own remarkable case.

"During the ten latter months of the year 1790 I had experienced several melancholy incidents, which deeply affected me, particularly in September, from which time I suffered an almost uninterrupted series of misfortunes, that afflicted me with the most poignant grief. I was accustomed to be bled twice a year, and this had been done once on the 9th of July, but was omitted to be repeated at the end of the year 1790. I had in 1783 been suddenly taken with a violent vertigo, which my physicians imputed to obstructions in the fixed vessels of the abdomen, brought on by a sedentary life, and a continual exertion of the mind. This indisposition was successfully removed by means of a more strict diet. In the beginning I had found the use of leeches applied to the arms particularly efficacious, and they were afterwards repeated two or three times annually, when I felt congestions in the head. The last leeches which had been put on previous to the appearance of the phantasms of which I am about to speak, had been applied on the 1st of March 1790; less blood had consequently been evacuated in 1790 than was usual with me, and from September I was constantly occupied in business that required the most unremitted exertions, and which was rendered still more perplexing by frequent interruptions.

"I had in January and February of the year 1791 the additional misfortune to experience several extremely unpleasant circumstances, which was followed on the 24th of February by a most violent altercation. My wife and another person came into my apartment in the morning in order to console me; but I was too much agitated by a series of incidents, which had most powerfully affected my moral feeling, to be capable of attending to them. On a sudden I perceived, at about the distance of ten steps, a form like that of a deceased person. I pointed at it, asking my wife if she did not see it? It was but natural that she should not see any thing; my question therefore alarmed her very much, and she sent immediately for a physician. The phantasm continued about eight minutes. I grew at length more calm, and being extremely exhausted, fell into a restless sleep, which lasted about half-an-hour. The physician ascribed the apparition to violent mental emotion, and hoped there would be no return; but the violent agitation of my mind had in some way disordered my nerves, and produced further consequences, which deserve a more minute description.

"At four in the afternoon the form which I had seen in the morning re-appeared. I was by myself when this happened, and being rather uneasy at the incident went to my wife's apartment, but there likewise I was prevented by the apparition, which, however, at intervals disappeared, and always presented itself in a standing posture. About six o'clock there appeared also several walking figures, which had no connexion with the first."

"After the first day the form of the deceased person no more appeared, but its place was supplied with many other phantasms, sometimes representing acquaintances, but mostly strangers: those whom I knew were composed of living and deceased persons, but the number of the latter was comparatively small. I observed the persons with whom I daily conversed did not appear as phantasms, these representing chiefly persons who lived at some distance from me.

"These phantasms seemed equally clear and distinct at all times, and under all circumstances, both when I was by myself and when I was in company, and as well in the day as at night, and in my own house as well as abroad; they were however less frequent when I was in the house of a friend, and rarely appeared to me in the street. When I shut my eyes those phantasms would sometimes vanish entirely, though there were instances when I beheld them with my eyes closed; yet when they disappeared on such occasions, they generally returned when I opened my eyes. I conversed sometimes with my physician and my wife of the phantasms which at the moment surrounded me; they appeared more frequently walking than at rest, nor were they constantly present. They frequently did not come for some time, but always re-appeared for a longer or shorter period, either singly or in company, the latter, however, being most frequently the case. I generally saw human forms of both sexes, but they usually seemed not to take the smallest notice of each other, moving as in a market-place, where all are eager to pass through the crowd; at times, however, they seemed to be transacting business with each other. I saw also several times people on horseback, dogs, and birds. All these phantasms appeared to me in their natural size, and as distinct as if alive, exhibiting different shades of carnation in the uncovered parts, as well as different colours and fashions in their dresses, though the colours seemed somewhat paler than in real nature; none of the figures appeared particularly terrible, comical or disgusting, most of them being of an indifferent shape, and some presenting a pleasing aspect. The longer these phantoms continued to visit me, the more frequently did they return, while at the same time they increased in number about four weeks after they had first appeared. I also began to hear them talk; the phantoms sometimes conversed among themselves, but more frequently addressed their discourse to me; their speeches were commonly short, and never of an unpleasant turn. At different times there appeared to me both dear and sensible friends of both sexes, whose addresses tended to appease my grief, which had not yet wholly subsided: their consolatory speeches were in general addressed to me when I was alone. Sometimes, however, I was accosted by these consoling friends while I was engaged in company, and not unfrequently while real persons were speaking to me. These consolatory addresses consisted sometimes of abrupt phrases, and at other times they were regularly executed.

"Though my mind and body were in a tolerable state of sanity all this time, and these phantasms became so familiar to me that they did not cause me the slightest uneasiness, and though I even sometimes amused myself with surveying them, and spoke jocularly of them to my physician and my wife, I yet did not neglect to use proper medicines, especially when they began to haunt me the whole day, and even at night as soon as I waked.

"At last it was agreed that leeches should be again applied to me as formerly, which was actually done April 20th, 1791, at eleven o'clock in the morning. No person was with me besides the surgeon; but during the operation my chamber was crowded with human phantasms of all descriptions. This continued uninterruptedly till about half-an-hour after four o'clock, just when my digestion commenced. I then perceived that they began to move more slowly. Soon after their colour began to fade, and at seven o'clock they were entirely white. But they moved very little, though the forms were as distinct as before; growing, however, by degrees more obscure, yet not fewer in number, as had generally been the case. The phantoms did not withdraw, nor did they vanish, a circumstance which previous to that time had frequently happened. They now seemed to dissolve in the air, while fragments of some of them continued visible for a considerable time. About eight o'clock the room was entirely cleared of my fantastic visitors.

"Since that time I have felt twice or three times a sensation as if these phantasms were going to re-appear, without, however, actually seeing any thing. The same sensation surprised me just before I drew up this account, while I was examining some papers relative to these apparitions, which I had drawn up in the year 1791."

As during disease creations of the fancy may thus emulate perception, in like manner may any fiction of opinion or feeling when the brain is disturbed appear reasonable, and mix among the sound conclusions and principles of the mind, and produce inconsistency of conduct and insanity.

Pure delirium, which results either from concussion or from inflammatory excitement of the brain, is remarkably contrasted in its moral features with insanity: in both the mind attaches reality to fictions; but in delirium the mind is either wholly absorbed as in a dream with its own creations, and preserves the power when strongly roused to momentary recollection, of directing itself justly to its situation; while in insanity truth and error are blended together, and when seen side by side are not distinguishable by the patient.

CHAPTER XII.

OF THE ORGANS OF THE SENSES.

Every part of the body appears to have the kind of sensibility calculated for its protection or the relief of its wants. Every part aches when fatigued by protracted exercise. A ligament, which is impassive to the knife, is the seat of severe and sickening pain, when forcibly stretched. The integuments which are not hurt by distension, feel acute pain upon division. An acid that acts upon the teeth produces a peculiar and unpleasant sensation in their nerves. Hunger is the sensation caused by the state of the nerves of the stomach when it craves a supply of food, and a sensation is referred to the bladder when it becomes distended, to lead to the expulsion of the urine.

But the term organ of sense is restricted to those parts which possess in addition a mode of sensibility, that gives us definite information of the qualities of external bodies.

An organ of sense is connected to the brain by one or more nerves, and consists of an expansion of nervous matter upon which material impressions are received, disposed in such a form and situation, and behind such media, as are calculated to concentrate upon it the impressions it is fitted to appreciate.

SECTION 1.

Of the Organ of Vision.

The optic nerve upon entering the eyeball expands to form a deep cup of soft grey nervous matter, termed the retina, which is distended by liquid or gelatinous substances.

If the eyelid be closed, and the eyes be voluntarily directed towards the left side, and pressure be made with the finger upon the outside of the right eye, the retina is squeezed between the coats and the humours of the eye, and concentric luminous circles are seen in the direction of the nose.

If this pressure be continued for twenty or thirty seconds, a broad undefined light increasing every moment in intensity rises immediately before the eye. It is remarkable that if the eyelids be open and there is light present, on a repetition of the last experiment, a dense cloud rises instead of the undefined light, and the eye becomes in a few seconds perfectly blind: when the finger is removed, in the course of three or four seconds the cloud seems to roll away from before the eye.

Thus it appears that sensations of light may be produced by mechanical pressure made upon the retina: and it is probable that the same result would ensue upon irritating the optic nerve. If the optic nerve be pricked in a pigeon, the pupil suddenly contracts, as when a bright light flashes upon the eye.

But the retina is organized to receive impressions of a different nature, and that so subtile as to excite no kind of sensation in any other organ. The received theory of the nature of these impressions is, that they consist in the impingement of inconceivably fine particles or rays of a peculiar and imponderable substance, termed light, upon the retina.

Luminous bodies are such as continually throw off rays of light. Rays of light move only in straight lines; and such is their velocity, that they travel from the sun to the earth, a distance of 95,000,000 miles, in 8⅛ minutes.

Those media are termed transparent which permit the passage of light; opake bodies are such as obstruct it. No material substances appear absolutely transparent or opake. Leaf gold transmits a greenish light, and on the other hand a depth of seven feet of water intercepts one half of the light which enters it.

A ray of light upon passing from one transparent medium into another of a different density, as from air into water, in a direction vertical to its surface, does not deviate from the straight line: but if it reach the second medium obliquely, it afterwards pursues a new course: it is bent or refracted *towards* the perpendicular, if the second medium be of greater density than the first: it is refracted *from* the perpendicular in the opposite case. Transparent substances are refractive in the ratio of their density and their combustibility. The degree of refraction again has reference to the angle at which a ray enters a transparent medium. All rays of the same kind transmitted by the same surface form with the perpendicular an angle of refraction, which is ultimately in a certain constant proportion to the angle of incidence; that is, for instance, one half, three-fourths, or two-thirds, according to the nature of the surface. Thus if the refractive properties of the substance were such, that an incident ray making an angle of one degree with the perpendicular would be so refracted as to make an angle of only half a degree with the same line, another ray incident at an angle of two degrees would be refracted, without sensible error, into an angle of one degree. But when the angles are larger, they vary from this ratio, their sines only preserving the proportion with accuracy; for example, if the angle of incidence at the supposed surface were increased to 90°, the angle of refraction would be 30° instead of 45°[a].

It follows from these premises: 1. that if the opposite surfaces of a transparent medium be plane and perfectly parallel, rays that are parallel when they enter it are parallel on leaving it: 2. that if one or both surfaces be exceedingly waved and irregular, rays that are parallel when they reach the uneven surface cease to be so on traversing it: and 3. that if the opposite surfaces be not parallel, and one be uniformly curved so as either to be hollowed or convex, the other uniformly curved or plane, parallel rays of light entering such a medium will either become uniformly divergent or convergent towards a point or focus: the former happens if the central part of the transparent medium be thinner than the edges, the latter if the central part be the thickest. Lenses are detached portions of transparent substances, which have one or other of the six forms included under the third supposition. Lenses are therefore either double-convex, or plano-convex, double-concave, or plano-concave, or convex on one side and concave on the other; a lens of the last description is termed a meniscus.

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[a] Young's Lectures on Natural Philosophy, vol. i. p. 411.

When a colourless solar ray is made to pass through a triangular prism of glass, it forms upon an opposite surface a coloured spectrum consisting of tints of red, orange, yellow, green, blue, indigo and violet. Newton thus discovered that the white solar light is composed of coloured rays, which are separable owing to their different degrees of refrangibility. When the coloured rays of the prismatic spectrum are recombined, they again form white light. According to Dr. Wollaston, four colours, red, green, blue and violet, in the proportions of 16, 23, 36, 25, constitute white light, and are capable in various combinations of producing sensations of every other colour. According to Dr. Young, red, green and violet, in the proportions of 2, 4, 1, are the elementary colours of the solar ray.

The path of a ray of light is again liable to be altered by reflection. All visible bodies that are not luminous are seen by means of rays thrown back from their surface. If a ray of light fall upon a surface perpendicularly, it is reflected perpendicularly. If a ray of light fall upon a surface obliquely and is reflected, the angles which it forms with a line vertical to that surface are called the angles of incidence and reflection. The law of reflection requires that the angles of incidence and reflection be equal, and that the incident and reflected ray be in the same plane with the imaginary vertical line.

Hence it follows, that rays which are parallel, when they reach a plane reflecting surface, are parallel when they leave it: that rays before parallel, which are reflected by an uniformly convex surface, diverge as from a focus situated behind it; that rays before parallel, which are reflected from a surface uniformly concave, converge towards a focal point.

The colour of luminous bodies depends upon the quality of the light they emit: the colour of bodies that are not luminous, when seen by white light, results from their absorbing some, and reflecting others of the elementary rays.

The term reflection is usually confined to those cases in which the rays are thrown back in a definite order, either in lines parallel to each other, or uniformly divergent or convergent. To produce this species of reflection a surface must be highly polished, in order that there may be an uniformity in the angles at which the greater part of the rays are returned.

If vision were as limited in its objects as the senses of taste or smell,—if sight were only to be gratified by the perception of pleasant colours, or we were intended only to discriminate by this means the presence of harmless and of noxious agents,—no mechanism would be required in the eye besides the expansion of the retina behind a simple transparent medium: and sight is sometimes reduced to this narrow scope, when it happens that the cornea becomes clouded through disease: in this case no impression is perceived beyond that of undefined light or colour.

When we consider sight in reference to the perception of colour only, some curious phenomena present themselves which deserve our attention.

When the eye has been intently fixed upon a coloured object, upon directing it to a white ground a spectrum of another colour but of the form of the first object is seen and remains for some time afterwards in the field of vision.

The second colour produced in this experiment is termed the accidental colour of the first.

The following table may serve to show a series of accidental colours.

Natural Colours.	*Accidental Colours.*
Red.	Blue with a small mixture of Green.
Orange.	Blue with nearly an equal part of Indigo.
Yellow.	Indigo with a considerable mixture of Violet.
Green.	Violet with a mixture of Red.
Blue.	Red with a mixture of Orange.
Indigo.	Yellow with a considerable mixture of Orange.
Violet.	Green with a considerable mixture of Blue.

White and Black again are reciprocally accidental colours.

From an experiment by the author of an article in the Edinburgh Encyclopædia, it appears that when a coloured spectrum is thus produced by an impression upon one eye alone, a spectrum of the original colour is liable to be perceived by the eye that has remained closed,—a phenomenon perhaps to be explained upon the continuity by nervous substance of one retina with the other.

The rays of light appear not to affect every eye in a similar manner. There are some who cannot distinguish the diversity of colour which the generality of men perceive; and we may suppose from the existence of the deoxidizing ray beyond the violet ray of the prismatic spectrum, that there are elements of light which might affect the vision of other beings with sensations of which we have no conception. The following statement, which I extract from the Medico-Chirurgical Transactions, describes the common form of defective vision.

"My eyes (says the writer of this narrative) are grey with a yellow tinge round the pupil. The colour I am most at a loss with is green, and in attempting to distinguish it from red, it is nearly guess-work. Scarlet in most cases I can distinguish, but a dark bottle-green I could not with any certainty tell from brown. Light yellow I know; dark yellow I might confound with light brown, though in most cases I think I should know them from red. All the shades of light red, pink, purple, &c., I call light blue; but dark blues and black I think I know with certainty. Though I see different shades in looking at a rainbow I should say it was a mixture of yellow and blue, yellow in the centre and blue towards the edges. I have red crimson curtains in the window of my bed-room, which appear red to me in candle-light and blue in day-light. The grass in full verdure appears to me what other people call red, and the fruit on trees when red I cannot distinguish from the leaves, unless when I am near it, and then more from the difference of shape than colour. A cucumber and a boiled lobster I should call the same colour, making allowance for the variety of shade to be found in both; and a leek in luxuriance of growth is to me more like a stick of red sealing wax than any thing I can compare it with."

The writer of this narrative mentions that a similar defect in vision had occurred in other instances in his family. By Dr. Nicholl's suggestion he made the curious observation, that on fatiguing his sight at different times with gazing upon spots of red and green on a white ground, the eye became painfully affected, but no accidental colour made its appearance[b].

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[b] Medico-Chirurgical Trans. vol. ix. p. 363.

If the objects of vision were limited to the communication of a vague and indefinite sense of shifting colours, the construction of the eye might have resembled that of the skin, and the optic nerve would require only to be incorporated with a vascular surface, and to be protected by a transparent membrane analogous to the cuticle. But we receive through sight exact information of the form and distance of objects, and we must expect to find in the eyeball a structure as elaborate and wonderful as the intelligence which it conveys to us.

The eye consists, 1. of a series of refracting media by which the rays of light that enter it are disposed in a certain order: 2. of an expansion of the optic nerve, so placed as to receive impressions of light in the most favourable manner: 3. of parts which provide for the equable introduction of light into the eye, and for its absorption after it has traversed the retina: and 4. of a spherical case in which the preceding parts are set.

1. The refracting media in the eyeball are the cornea, the aqueous humour, the lens or crystalline humour, and the vitreous humour.

The cornea is formed of a transparent dense elastic laminated substance, being a segment of a smaller sphere than the globe of the eye. As its surfaces are nearly parallel, it deserves perhaps rather to be described as a piece in the case of the eye, than as part of the mechanism by which light is modified in its passage to the retina.

The aqueous humour is a liquid, which consists of water impregnated with albumen, gelatin, and muriate of soda: its refractive power, according to the researches of Dr. Brewster and Dr. Gordon, may be estimated at 1.3366, that of water being 1.3358.

The form of the aqueous humour depends upon the parts which confine it. The aqueous humour is contained between the cornea and the lens, and forms a meniscus. Its specific gravity is 1.0088.

The crystalline is a double convex lens, of which the anterior surface is flatter than the posterior: its substance is gelatinous, and of much denser consistence at the centre than near the surface; it is contained in a thin capsule. Its composition, according to the analysis of Berzelius, is as follows:

Water	58
Peculiar matter	35.9
Muriates, lactates, and animal matter soluble in alcohol	2.4
Animal matter soluble only in water with some phosphates	1.3
Portions of the remaining insoluble cellular membrane	2.4
	100.0

The refractive power of the different parts of the crystalline humour, according to Dr. Brewster and Dr. Gordon, is as follows:

Refractive power of the outer coat of the crystalline	1.3767
Refractive power of the middle coat of the crystalline	1.3786
Refractive power of the central part of the crystalline	1.3990
Refractive power of the whole crystalline	1.3839

The specific gravity of the crystalline is 1.0765.

The vitreous humour is a liquid resembling the aqueous humour; but it is contained in a proper capsule termed the hyaloïd membrane, from which innumerable membranous processes pass inwards to form a series of cells in which the liquid is lodged; the vitreous humour nearly fills the eyeball. The lens is imbedded in its fore part; the hyaloïd membrane upon approaching the margin of the lens splits into two layers, one of which passes behind the lens *adhering to* its capsule, the anterior passes upon the fore part of the lens and becomes *identified with* its capsule. Air may be blown into the circular channel between the two layers of the hyaloïd membrane at the margin of the lens: this channel is termed the canal of Petit.

The refractive power of the vitreous humour is 1.3394[c]. In specific gravity and chemical composition it resembles the aqueous humour[d].

The optic nerve perforates the coats of the eye towards the inside of its axis, shrinking at the same time to half its former diameter. The retina, which is commonly described as the expansion of the optic nerve, is a thin soft layer of nervous substance, embracing the vitreous humour, and extending to no great distance from the margin of the cornea, or to the commencement of the ciliary plicæ.

If the sclerotic coat be dissected off, and the chorioïd drawn off with forceps under water in the manner described by Dr. Jacob, the outer surface of the retina is exposed; and if the eye be fresh, a thin membranous tunic may be detached from the nervous matter by gentle pressure with the handle of a scalpel: in eyes that are not fresh, the same substance detaches itself in shreds from the retina. In some instances again, the nervous matter admits of being scraped from an inner membrane, which is distinguishable upon the vitreous humour through the branching of blood-vessels in its texture. In a preparation which had been three years in spirits, a membranous layer was distinctly to be seen continued from the retina to the margin of the ciliary processes.

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[c] Edinburgh Phil. Journal, vol. i. p. 43.

[d] Thomson's Chemistry, vol. iv. p. 521.

The retina is not tensely stretched upon the vitreous humour, but has a tendency to lie in shallow folds; one of these folds is exactly in the axis of the eye, and conceals a circular deficiency of nervous matter, discovered by Soemmering: the foramen is $\frac{1}{33}$ of an inch in diameter, and the nervous matter around it for the breadth of $\frac{1}{20}$ of an inch is of a bright yellow.

The chorioïd is a thin membrane which immediately supports the retina: it is very vascular; its veins, the branches of which describe parallel curves, are termed vasà vorticosa: it is supposed to be separable into two layers, the innermost of which is termed the tunica Ruyschiana. Towards the margin of the cornea, the chorioïd adheres firmly to the sclerotic, constituting what is termed the ligamentum ciliare: within, it is thrown into plicæ, which are termed the ciliary processes; they indent the hyaloïd membrane, where it splits to form the canal of Petit.

The iris is a thin membranous curtain, which is spread behind the cornea; it is attached to the ligamentum ciliare, and floats in the aqueous humour: it has a circular perforation in its centre called the pupil. The iris is very vascular, so as when injected to appear composed of vessels only: it is likewise largely supplied with nerves termed ciliary nerves, which are derived from the third and from the first division of the fifth; these make their way to the iris between the chorioïd and the sclerotic, after having perforated the latter at the back part of the eyeball. Sir E. Home describes circular fibres at the unattached margin of the iris. The posterior surface of the iris is termed the uvea.

The inner surface of the chorioïd and of the ciliary processes, and the posterior surface of the iris, secrete a thick black mucus termed the pigmentum nigrum: some of this pigment is found between the chorioïd and sclerotic. The colour of the eye is the colour of the iris, which results from the conjoined effect of the black pigment, and of the natural texture of the iris. In Albinoes the pupil appears red, and the iris pink, owing to the total absence of pigmentum nigrum in these individuals.

The sclerotic is a deep cup of a thick and strong white fibrous texture, which contains and protects the membranes and humours that have been described. The cornea is let in like a watch-glass to a circular aperture in the front of the sclerotic; it is kept in its place by its continuity of substance with the sclerotic, and by the outer substance of the sclerotic lapping over it.

The first inquiry which would occur to the mind upon contemplating the several pieces of the above curious mechanism, we may suppose to be,—what changes in the arrangement of the rays of light are produced by their passage through the transparent humours of the eye?

A simple experiment serves to answer this question.

Take the eye of an animal recently killed, and remove with care the back part of the sclerotic coat; interpose the eye thus prepared between you and a luminous body, as for instance the flame of a candle, so that the aperture of the pupil may be turned towards the luminous body, and the exposed part of the chorioïd presented to your view: a distinct inverted image of the flame of the candle will appear formed upon the chorioïd or retina: and if two luminous objects be placed before the prepared eye, you may ascertain by removing one, that its image was painted on the side of the retina, the reverse of its real place.

Thus it appears that the effect of the refractions which take place in the eye is to arrange the rays of light, when they reach the retina, into an exact but inverted picture of the objects from which they last proceeded. But in order to form such a picture, all or the greater number of the rays which enter the pupil from single points of the object, must be assembled in focal points upon the retina; and the several points of the object represented must be at the same relative lateral distance from each other upon the retina, as when they left the surface of the object. To accomplish the latter purpose the retina is concave, but for which form the picture upon it would be distorted. The importance of the former point is shown in cases wherein a want of exactness in the refractive power of the eye prevents the arrangement of the rays in focal points upon the retina, and produces an indistinctness of vision which is remedied only by the employment of glasses. In young persons the cornea is sometimes too prominent: this kind of eye is termed myopic, and is capable of seeing those objects alone distinctly, which are brought within a short distance of the cornea. At a greater distance the vision of a myopic eye is confused, unless a divergent lens be used to rectify its unusually great refractive power. In old persons the cornea is commonly too flat, constituting the presbyopic eye; and those objects alone are distinctly seen that are at a distance. The rays, which enter the pupil of a presbyopic eye from objects that are near, are not brought to focal points owing to the defective power of the flat aqueous humour, unless a convergent lens be used. In the myopic eye parallel rays are brought to a focus, and disperse again before they reach the retina: in the presbyopic eye the focal point of rays, that are divergent when they reach the cornea, would be situated behind the retina.

We may next inquire whether the sum of the information which we receive from vision be the direct result of the impression made upon the retina, or be derived in part from other sources. Upon this question a decisive experiment is recorded by the philosophic Cheselden, who carefully observed, after performing the operation of couching, the effect of the first impressions of sight upon his patient.

"This young gentleman either had been born blind, or had lost his sight so early, that he had no remembrance of ever having seen: the blindness arose from a cataract, or opake crystalline, in both eyes. Like other persons who have ripe cataracts, he was not so blind but that he could discern day from night, and for the most part in a strong light distinguish black and white and scarlet. When he first saw, he was so far from making any judgement about distances, that he thought all objects whatever touched his eye (as he expressed it), as what he felt touched his skin. He knew not one thing from another, however different in shape or magnitude; but upon being told what things were, whose form he before knew from feeling, he would carefully observe that he might know them again. Two months after being couched, his attention seems to have been drawn to the effects of painting, which he then first and at once comprehended: but even then he was no less surprised, expecting the pictures would feel like the things they represented, and was amazed when he found those parts which by their light and shadow appeared round and uneven, felt only flat like the rest; and asked which was the lying sense, feeling or seeing?

"Being shown a small miniature of his father, and told what it was, he acknowledged a likeness, but was vastly surprised; asking how it could be that a large face could be expressed in so little room, saying it should have seemed as impossible to him, as to put a bushel into a pint. At first he could bear but very little light, and the things he saw he thought extremely large; but upon seeing things larger, those first seen he conceived less, never being able to imagine any lines beyond the bounds he saw. The room he was in, he said, he knew to be but part of the house, yet he could not conceive that the whole house could look bigger. Before he was couched, he expected little advantage from seeing worth undergoing an operation for, except reading and writing; for he said, he thought he could have no more pleasure in walking abroad than he had in the garden, which he could do very safely and readily; and even blindness, he observed, had this advantage, that he could go any where in the dark, much better than those who can see: and after he had seen, he did not soon lose this quality, nor desire a light to go about the house in the night. He said every new object was a new delight, and the pleasure was so great that he wanted ways to express it: but his gratitude to Mr. Chesselden he could not conceal, never seeing him for some time without tears of joy and other marks of affection. A year after first seeing, being carried upon Epsom Downs, and observing a large prospect, he was exceedingly delighted with it, and called it a new kind of seeing. And now being lately couched of his other eye, he says that objects at first appeared large to this eye; but not so large as they did at first to the other; and looking upon the same object with both eyes, he thought it looked about twice as large as with the first couched eye only, but not double that he can any ways discover [e]."

By these interesting details it appears evident that the sense of sight originally gives us no information respecting the distance or real magnitude of objects, and that there is no essential resemblance between the ideas communicated by vision and by feeling. The early years of life are employed by us in learning to interpret the signs of external objects which we become acquainted with through vision. As soon as there is intelligence in an infant's gaze, it extends its hands to grasp and examine each object in succession which attracts its sight.

But physiologists are apt to incur the error of attributing too much of the intelligence which we seem to receive from vision to extraneous sources, and are liable to underrate the original capacity of the eye, and the quantity of information which we primarily derive from this organ. It is observed, that objects are painted reversed upon the retina, and we are supposed to acquire a knowledge of their real position through the sense of touch;—that the size of objects as they are painted upon the retina bears no proportion to their apparent size, and the latter is supposed to be a fiction of the judgement;—that we appear to see right lines, when in fact no lines can be represented on the retina, which are not curved at least in one sense, and the notion of a right line is supposed to be derived from touch, the geometrical sense as it has been termed.

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[e] Phil. Trans. abridged, vol. vii. p. 491.

It becomes us therefore to inquire, whether there exist any law in the constitution of the eye, by which notions in any degree definite, respecting the size and figure and position of objects, are essentially communicated to us through vision without the assistance of the other senses. Of one of the questions brought forward, a sufficient elucidation seems contained in the general fact, that all lines which cut the retina in one plane, are seen as right lines. Observations of this description, which contain in a single expression an entire class of phenomena, are indeed the proper objects and seem the limits of philosophical research; yet in such a case there is still room to investigate, whether a law, though embracing an entire class of phenomena, may not yet admit of being merged in an expression still more general. A remarkable instance of this kind happens to be furnished by the present subject, in the discussion of which I shall have to cite some experiments contained in Scheiner's Fundament: Optic: the full value of which does not appear to have been appreciated by modern writers on vision, although they were applied by Dr. Porterfield and Dr. Reid to the solution of the most curious of the phenomena before us, vision namely of objects in their true position by means of inverted images on the retina.

Let me premise that the mind attends at a given instant to one point only of an image delineated on the retina: so that our seeming perception of an extensive surface is made up at any moment of a perception of one point and a conception of the rest. Hence it is that it requires an effort of continued attention to enable us to comprehend the figure of a new object, (as for instance a geometrical diagram, which we happen to see for the first time,) while the eye seems to catch at a glance each part of a more complex figure, with which we were previously acquainted: the recollection in the latter case assists us in forming that conception of the whole, which seems till we analyse it to be a part of vision. Hence the striking effect of a clever sketch, in which the imagination vividly supplies what is wanting, and seems to give life and colour to a scene delineated by a few skilful touches of the pencil. Hence too, the alarm reasonably produced on a superstitious mind by objects imperfectly seem in the dusk, the fancy adding to the outline or motion imperfectly caught, an image which the mind realizes as a part of sensation.

It may serve to illustrate the preceding remarks that the central part only of the retina appears fitted for accurate vision; so that we habitually turn the axis of the eye to each point in succession even of a minute object on a plane surface, in attentively regarding it. While we thus shift the surface of the retina, on which the object is delineated, the image does not appear to move; nor if we rapidly roll the eye from side to side, do objects before us appear unsteady. An oscillating motion of the eye is indeed constitutional with some persons: it is constantly, I believe, observed in Albinoes, whose eyes cannot bear bright day light; and has been seen in persons with grey eyes, who have had no conscious peculiarity of vision.

Let us proceed to examine whether there exist any original law of vision, which determines us to refer the several points of an image formed upon the retina to one *direction* rather than to another.

It has been just observed that when the eye is quickly moved from side to side, we are satisfied that the scene before us remains steady, and does not shift its place. Our conviction however in this instance is the result of reflection. When the eye moves, stationary objects change their apparent place in regard to *it*; that for instance which was in front of the eye is now situated to its right or left: but we know that the position of the eye has been altered; and that, supposing the object contemplated to have continued at rest, its image must, when the eye moved, have been transposed to another part of the field of vision. Whether we direct the eye from the centre to the margin of an object before us, or the place of the object be so shifted as that its margin is brought opposite the axis of the eye, the effect upon the retina is the same. The visual impression in either case equally conveys the idea of change of place; and we refer to other sources for intelligence whether the eye moved away from the object, or the object from before the eye. But the following experiments show more persuasively the fact, that an object really shifts its visual place, when painted in succession upon different points of the retina.

I. If the head of a pin strongly illuminated be viewed with one eye, at a distance of four inches, that is to say within the common limit of distinct vision, the object is seen to be large and imperfectly defined, the outermost cone of rays, which enters the pupil from each point having been too divergent to be collected to a focus on the retina. If a card pierced with a pinhole be interposed between the eye and the object, the latter may be seen distinctly defined through the pinhole, by means of rays that have entered the pupil nearly parallel, with a slightly divergent tendency. But the object may be seen by rays passing either through the upper or lower part, the right or left side, or the centre of the pupil. Upon shifting the card for this purpose the object appears to move in an opposite direction. Or if three pinholes be made, one in the centre, and one at either side, the object appears tripled, and if one of the side holes be closed, the opposite of the three objects disappears; if for instance the left hand pinhole be closed, the right object disappears.

2. The preceding experiment may be varied by selecting for observation an object beyond the limits of distinct vision, as for instance the flame of a candle at ten feet distance[f]. In this case the obscurity of the image results from the rays of light having been insuffi-

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[f] I quote this experiment and the preceding, nearly in the words of Dr. Reid, and it happens that the distance selected suits my own eye.

ciently divergent upon entering the eye, and having formed a focus anterior to the retina, before reaching which they have again dispersed. In this case again, the interposition of the perforated card on a similar principle restores distinctness to the object, but with this difference from the preceding,—that if the card be moved to one side, the object moves to the same side. If the card be perforated in several points at a line's distance, the object again is seen multiplied in the same proportion; but the closing a pinhole on one side of the centre obliterates the image upon the same side.

3. It is well known that when the axis of the eye is turned inwards, and pressure is made upon the outside of the eye, concentric luminous circles are seen in the direction of the nose: if the pressure be shifted to the upper and outer part of the eyeball, the spectrum is depressed; if the pressure be transferred to the lower and outer part of the eyeball, the spectrum rises or is seen at the inner and upper part of the eye. It will be observed that the form of the spectrum has a very accurate relation to the impression made upon the retina; if the pressure be made with the end of the finger, the spectrum is nearly circular, if with the narrow end of a paper-folder, the spectrum is oval.

The experiments, which have been detailed, establish the fact, that the visual place of an object shifts, when its image is transferred to a different part of the retina, and thus in some degree illustrate the principle upon which we arrive through sight at a notion of the relative place of objects; but they leave in their original obscurity the source of our precise visual impressions respecting the true direction of objects, and the paradoxical fact that we see objects erect by means of inverted pictures upon the retina. The following experiment, however, taken in connexion with the preceding, fully elucidates these difficult questions.

4. If the head of a pin strongly illuminated, be viewed at the distance of eighteen inches, its outline is distinct and clear; the rays passing from each point of the object are brought to a point upon the retina; but these rays reach the retina at different angles; and by interposing a card perforated with a single pinhole, the object may be seen by rays, which enter the upper part, or the lower part, or the centre of the pupil. But no change in the visual place of the object occurs in this instance, as the card is shifted; nor is the image multiplied, when seen through several pinholes in the card.

We may hence infer that the angle, at which a ray of light impinges upon the retina, does not alter the apparent direction of an object: but that at whatever angle a ray arrive at a given point upon the retina, the impression is referred to one and the same direction. This direction appears to be a line vertical to the point of the retina, where the ray impinges. If the eyelids be closed and pressure be made upon the eyeball with the finger above, below, or at either side, (the eyeball being so turned as to expose the retina to the pressure,) the luminous circles in each case appear directly opposite to that part of the retina, on which the physical impression is made.

Thus it appears to be a law of vision, that *we see each point of an object in the direction of a line vertical to the point of the retina, on which it is delineated:* and the inversion of the picture proves to be an accident only, attending the arrangement of the rays of light in such an order, as the arbitrary form of the retina requires. By retracing our steps from the point, at which we have now arrived, we may attain perhaps yet clearer notions of the wonderful art displayed in the construction of the eye. The following different ends are seemingly comprehended in its design. 1. Each point of the retina being likely to receive the impression of rays of light at various angles is so constituted as to refer visual impressions to one direction only, in order that the information conveyed to us may be consistent. 2. The retina is placed behind refractive media, which collect in one point upon its surface the rays that enter the eye from a given point of an object, in order that the same part of an object may not be seen in several places at once. 3. Each point of the retina has a definite inclination, in order that vision may be true; or in other words, in order that the visual direction of an object may correspond with its tangible direction. 4. The retina is concave, in order to simplify the optical contrivances, by which the cones of rays that enter the eye are brought to focal points upon it. 5. The retina being concave, the images of entire objects are necessarily reversed upon it to be seen in their true position; but the retina might have been convex, and then for correct vision the images of objects would have been delineated upon it erect.

We may now accurately discriminate what impressions in vision are essentially derived from the constitution of the eye, and what from a comparison of sight with the evidence of another sense.

The property of vision above demonstrated is calculated to give us definite impressions respecting extension in one plane only. Instead of determining the place of objects, it defines their direction; instead of informing us of their real magnitude, it defines their visual height and breadth. The eye has no original measure for distance. The lad couched by Chesselden thought that visible objects touched his eye. The eye gives us no notion of real magnitude: when the eye is fixed upon a point on the wall of a narrow chamber or in the vault of heaven, it seems to command an oval or circular area of equal visual dimensions: a foot rule under these circumstances held at the distance of a few inches before the eye measures equally the side of a room or a segment of the firmament.

We judge of the distance of objects by the greater or less indistinctness of colour and outline, which we learn from experience belongs to objects when more or less remote. We judge of their real magnitude by a calculation founded upon the *apparent* size and probable distance of objects. Hence we are liable to continual mistakes on these points. An Englishman in the clear atmosphere of Italy supposes distant objects to be nearer to him than they are. We think the moon larger when near the horizon than when above our heads; near the horizon the moon is more dim, we therefore by analogy suppose her more remote; but her visual diameter is really the same, and therefore we are persuaded her disk is broader: a crow flying near us in a mist loses its distinct outline, and might through a similar fallacy be magnified into a traveller on horseback.

Let me finally remark, that the law above stated respecting our vision of right lines is obviously a deduction from or contained in the more general law which has been last illustrated. If it be true that each point of an object is seen in a direction vertical to the point of the retina on which it is represented, it follows that a line delineated upon the retina as cutting it in one plane, will appear a right line, whether it represent an object really curved or straight: our practical *persuasion* of the curvature or straightness of such a line results from the mode in which it happens to be shaded. Let me take this opportunity of remarking that I have used the expression of images or pictures upon the retina, to avoid circumlocution, and to denote merely the arrangement of the rays of light upon the expanded nerve: it is obvious that during vision no sensible image is formed upon the retina.

Hitherto we have considered sight in reference to vision with a single eye; but habitually we employ both eyes; and it is interesting to inquire what are the conditions which render vision under these circumstances single or double.

It is to be borne in mind that the centre of the retina, from whatever cause it proceed, furnishes the most distinct vision. Hence in looking at a point of an object we invariably direct the axis of the eye towards it; and when we look with one eye at a succession of objects placed *directly* before us, but at different distances, the optic axis is seen to incline inward when we regard the nearest object, and to increase its direction outwards as we view those which are more remote.

Now when we look with both eyes at any one of such a series of objects, it appears single, the rest appear double. This familiar but remarkable phenomenon has given rise to the hypothesis that there are corresponding points in either retina: it is supposed that when an object is delineated upon those points of the two retinæ which are naturally associated, it appears single, and double under other circumstances. But it seems unnecessary to resort to this explanation of the fact. It has been already shown that objects are seen in a definite direction; when therefore it happens that the visual direction of an object is the same or nearly the same for both eyes, that object appears single; when different, the object appears double. In both cases two objects are seen: but in single vision they are seen in the same place, and therefore necessarily appear to form but one: the images coincide, and are essentially indistinguishable.

It is well known that if we close one eye, and attempt to judge of distance with the eye that remains open, our conjectures are wide of the mark. This circumstance results from our habitually taking the impression of both eyes in vision, which is much more full and strong than the impression made on one eye only. Our judgment is uncertain in the instance adduced from our having but half the data, upon which it is usually formed.

For perfect vision with the human eye it seems requisite that the rays of light should undergo no reflection after reaching the retina. The pigmentum nigrum appears intended to absorb the rays of light which have once impinged upon the nerve. Those in whom this secretion is wanting have a weak sight, and only see distinctly in an obscure light. We may suppose the retina in such cases liable to be dazzled by the reflection of part of the light from the vascular chorioïd. On the other hand there are animals, which habitually seek their prey in the dusk; in these and in several instances where the final cause of the peculiarity of structure is not equally obvious, the back part of the chorioïd is covered with a membrane termed the tapetum lucidum, which presents a brilliant reflecting surface. The lustre of the eyes of cats in an obscure place results from this cause. It is supposed that the double impression of a low degree of light upon the retina serves as a substitute for the single impingement of brighter light. M. Magendie ingeniously compares with this disposition of parts a structure observed by himself in the eyes of birds remarkable for their acute vision. In the eagle, the retina lies in numerous folds, so that we may suppose it several times perforated by the rays of light.

To equalize the quantity of light admitted within the eye under different circumstances appears one of the functions of the iris. It is well known that the pupil is diminished when light is more intense, and enlarges under a more obscure light. What principally deserves attention in this phenomenon, is the mechanism through which a change in the diameter of the pupil is produced.

The most ready manner of accounting for the alteration of the size of the pupil, is to suppose the substance which forms the unattached margin of the iris irritable. In many instances the iris distinctly consists of two portions, which appear from their colour to be differently organized, of an outer broader part, and an inner narrow ring. In birds especially, in which the pupil is as mobile as their vision is perfect, the inner ring of the iris generally presents a hue totally different from the outer, and beginning at an abrupt line. In the ring-necked parroquet of China, the inner ring is grey or slate-coloured, the outer ring yellow or orange. If the eye of this animal be attentively watched, the grey inner ring of the iris may be observed, when the pupil contracts, to become sensibly narrower, as if it were the part that acted. I have not observed a similar change, however, in the iris of any other bird, though many have the iris similarly coloured.

Upon watching the eye of a cat or of a hawk, the contraction of the pupil appears often to be voluntary. When the eye of the animal is bent upon an object that excites its attention, yet which does not shift its position, the pupil may be seen to enlarge and to contract alternately. The animal is probably employed in examining the object under different lights by intentionally admitting more or fewer rays through the pupil.

Another remarkable circumstance concurs with the preceding in establishing a resemblance between the action of the iris and that of voluntary muscles. The iris receives nerves from two sources, from the sentient part of the fifth, and from the third: the main part of the latter is distributed as a voluntary nerve to the muscles of the eye. Now if the head of a pigeon be cut off, and, instantly after, the upper part of the cranium be removed, and the entire brain be taken out, on pinching the portion of the third nerve which remains attached to the eye, the iris acts suddenly, just as the biceps flexor cubiti acts in an animal recently killed, when the nerve which supplies that muscle is pinched. A similar injury to the fifth nerve produces no visible effect.

If the third nerve be divided in the cranial cavity, while the animal is alive, the pupil immediately dilates to the utmost, and remains immoveable, the iris being seemingly paralysed. When again the third nerve is pinched in the cranial cavity of a young cat instantly after death, the iris will occasionally act as in the pigeon. In either case the exposure of the nerve must be very promptly executed, or the effect described does not happen.

I have already mentioned the curious changes which M. Magendie observed to ensue gradually in the eyes of rabbits after the division of the fifth nerve; but another remarkable effect followed instantaneously: the pupil became diminished to a point, and the eye was apparently blind. Blindness however had not appeared to ensue in pigeons in which I had previously made the division of the fifth nerve, and I have subsequently ascertained that the division of the fifth nerve in the cranial cavity of a cat produces no such effect; and M. Magendie has likewise since found that if a bright light be concentrated with a lens upon the eye of the rabbit after the same experiment, the retina is evidently sensible to the impression. But the contraction of the pupil in this experiment remains unexplained;—a singular anomaly, placed perhaps in a still stronger light by the following experiment which I have repeated several times. A young rabbit being killed, the upper part of the cranium was immediately removed, together with the cerebrum. The optic nerve thus exposed, was pricked, and then divided; no movement of the iris ensued: the third nerve was pricked and then divided; the iris exhibited no change: the fifth nerve was then slightly compressed, and the pupil became contracted not suddenly but slowly and gradually, and then slowly dilated; upon dividing the fifth, the pupil became contracted to the utmost, but in a gradual manner although more promptly than before, and remained fixed. It is difficult to explain this singular phenomenon. But it should be mentioned in connexion with it, that in the cat and pigeon, in which the iris is paralysed by the division of the third nerve, and the pupil remains permanently dilated afterwards, the pupil dilates likewise when death takes place. In the rabbit on the contrary, the pupil contracts as soon as ever life ceases.

What may be the properties of the human iris remains in obscurity: it is not impossible that its action may be voluntary, but being disused except on two especial occasions (when the light thrown on objects or their distance varies), we perhaps lose our original controul over it through neglect: such too appears to be the condition of the muscles of the soft palate which we seem capable of moving in one or two combined actions only; but they are not the less under the influence of the will; and some persons are found, according to Magendie, who can move them separately at pleasure.

If light be too intense, the eye is dazzled, and objects are no longer distinguished: if the quantity of light be very inconsiderable, no adequate impression is made upon the retina, and vision does not take place. If again we enter suddenly an obscure chamber not absolutely dark, out of bright daylight, for a few seconds we discern nothing; but the eye quickly accommodates itself to the obscurer light, and vision is restored.

Under any advantage of light it appears that objects are only perfectly seen when within a certain range of distance. The image of an object upon the retina is diminished in proportion as its distance is increased; and when the space the image occupies is reduced to less than a certain dimension, it wholly ceases to produce sensation. This remark, it will be seen, bears upon an expression that has been employed in the preceding pages, and which though it be convenient to retain it, must be taken with some modification of its meaning. The cone of rays that enters the pupil from any visible point of an object is said to *converge to a focal point* upon the retina; it is obvious, that such a focal point is very different from a point in the strict mathematical sense of the word; it signifies only a very small circle.

But there is another cause, why the range of perfect vision has its limits, which has been already in part illustrated. It appears by the phenomena of myopic and presbyopic eyes, that a very nice arrangement of the rays of light upon the retina is necessary for distinct vision; it is not therefore wonderful that we cannot see perfectly at all distances; but on the contrary it ought rather to excite our admiration, that we are able to see objects with any degree of distinctness at more distances than one. When we consider how different the angle must be at which the marginal rays of each cone reach the eye from objects at different distances, it is reasonable to suppose that the focal length of the eye adapted to one case must be essentially unfit for any other. Nevertheless we are not conscious of making an effort to produce a change in the refractive power of the eye, at the time we direct our attention from a near object to one more remote.

A simple experiment, however, serves at once to prove, that when the eye is capable of seeing distinctly objects at one distance, it is unfit to distinguish objects at any other, and that we possess a voluntary power of instantaneously altering the focal length of the eye.

If a clear straight line be drawn with a pen upon a plane white surface from a foot to two feet in length, and the eye be placed just above the level of the white surface, and be directed along the black line, the latter will appear distinct at one point only, on either side of which it appears confused, and spread over a widening space. If the eye be fixed upon a point nearer than that first looked at, but within the limits of distinct vision, the nearer point becomes defined, and the remote point confused.

In Dr. Young's optometer a single line is seen through several narrow slits in a thin brass plate, two or more of which correspond with the aperture of the pupil. Hence it happens, that except at the point to which the eye is adjusted, the line appears double or triple; or the lines are seen to cross at the point, at which vision is distinct; and the crossing of the lines may be made to appear more or less remote by directing the attention successively to different points of the surface. By means of a convergent lens, the effect of infinite distance is given to the length of a few inches upon the optometer, and a graduated scale shows the true distance at which vision is distinct.

At eighteen or nineteen years of age, a good eye should be capable of adjusting itself to objects situated at any point between five or six inches from the eye and infinite distance, or even of bringing to a focal point upon the retina convergent rays. As life advances, the power of adjusting the eye is continually diminished by an increasing inability to distinguish near objects. Between fifty and sixty, the refractive power of an eye originally perfect is qualified to bring to a focus parallel rays only, or the power of adjustment is wholly lost. A myopic eye does not, as is usually supposed, acquire a long sight in the advance of life; it possesses at first a certain power of adjustment, as for instance, between four and nine inches; and when the power of adaptation is lost, its vision remains perfect at the remotest point to which its power of adjustment originally extended.

The mechanism by which the eye alters its focal length remains in obscurity, notwithstanding the numerous attempts that have been made to explain it.

An experiment made by Dr. Young, is fatal to the supposition that the change produced consists in an alteration of the form of the cornea. A convex lens fixed in a socket, which contained water, and the edges of which were secured with wax, was applied to the eye, so that the cornea entered half way into the socket and was every where in contact with the water: the eye immediately became presbyopic; but upon the addition of another convex lens to make up for the loss of the convexity of the cornea, vision was restored to its natural state, and the eye regained the power of adjustment[g].

Other experiments, made by Dr. Young, set aside the supposition that a change takes place in the length of the axis of the eye, to fit it for vision at different distances;—if experiments are indeed necessary to disprove the application of any considerable pressure on this delicate organ, of which we have no consciousness at the time when by this hypothesis it should take place.

Dr. Young himself concludes that the means of adjustment consist in a change of form in the crystalline, the fibres of which he describes, and which he supposes to be irritable. But it does not appear from direct experiment that the crystalline possesses irritability; and if faith can be attached to a single well attested observation upon a point so delicate, the instance of Henry

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[g] Phil. Trans. vol. xci. p. 58.

Miles, recorded by Sir Everard Home, proves that the eye may retain its power of adjustment after the removal of this part[h].

The only evident change in the eye when adjusting its focal length to different distances, is an alteration in the diameter of the pupil. The pupil enlarges when a distant object is seen, and diminishes when we look at a nearer point. Upon a superficial analogy we might conclude that these changes are sufficient to produce the requisite alterations of the focal length of the eye: for by viewing objects through a series of pinholes in a card, the largest smaller than the aperture of the pupil and each of the rest in succession smaller than the last, the eye is rendered capable of seeing distinctly at the distance of four, of three, and even of two inches. When however the correctness of this hypothetical explanation is put to the test of direct experiment, it proves to be fallacious.

In investigating the point under consideration I availed myself of the assistance of Mr. Robinson of Devonshire-street, a very ingenious artist, who makes the optometer contrived by Dr. Young, and who is very conversant with the use of that instrument.

A room was darkened by half closing the shutters, and I attentively observed the state of the pupil, when Mr. Robinson directed his eye to a definite point upon the optometer: the pupil was of course considerably dilated: the shutters being then opened, the pupil instantly contracted, but the point upon the optometer at which the lines crossed did not shift its place.

When by some practice I had accustomed my own eye to the use of the optometer, I compared its range in the brightest and in the obscurest light in which the lines were visible, and observed no apparent difference in the two cases. Mr. Robinson made a similar observation. Either of these experiments prove that the change in the size of the pupil is not the means by which the adjustment of the eye to distances is effected. But an additional fact may be mentioned. In an old lady of sixty-seven, whose sight in early life was remarkably good, but whose eyes can now only bring to a focus parallel rays, the pupil retains its mobility perfectly under variations of light; and even sensibly moves upon her making ineffectual attempts to read without spectacles a page held at different distances from her.

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[h] Phil. Trans. vol. xcii. p. 8.

It deserves remark, that after the eye has had some practice in accommodating itself to exact vision at different distances, it is easy when an object, as for instance a screen, is held at the distance of six or seven inches, and has been for a few seconds distinctly seen, to adjust at pleasure the focal length of the eye for vision at a remoter point: under these circumstances the object held before the eye becomes confusedly seen; the optic axes diverge, and the pupil dilates. In a similar way the eye may be adjusted at pleasure to a shorter distance, at which no visible object is situated: thus a power appears to be acquired of voluntarily influencing the action of the iris.

I have already observed that one part of the retina appears habitually used for accurate vision: I cannot better illustrate this subject than by making the following extract from the Philosophical Transactions.

"The visual axis (observes Dr. Young) being fixed in any direction, I can at the same time see a luminous object placed laterally at a considerable distance from it; but in various directions the angle is very different. Upwards it extends to 50 degrees, inwards to 60, downwards to 70, and outwards to 90 degrees. These internal limits of the field of view nearly correspond with the external limits formed by the different parts of the face, when the eye is directed forwards and somewhat downwards, which is its most natural position; although the internal limits are a little more extensive than the external; and both are well calculated for enabling us to perceive the most readily such objects as are likely to concern us. Dr. Wollaston's eye has a larger field of view, both vertically and horizontally, but nearly in the same proportions, except that it extends further upwards. It is well known that the retina advances further forwards towards the internal angle of the eye, than towards the external angle; but upwards and downwards its extent is nearly equal, and is indeed every way greater than the limits of the field of view, even if allowance is made for the refraction of the cornea only. The sensible portion seems to coincide more nearly with the painted chorioïd of quadrupeds; but the whole extent of perfect vision is little more than ten degrees; or more strictly speaking, the imperfection begins within a degree or two of the visual axis, and at the distance of five or six degrees becomes nearly stationary, until at a still greater distance vision is wholly extinguished. The imperfection is partly owing to the unavoidable aberration of oblique rays, but principally to the insensibility of the retina; for if the image of the sun itself be received on a part of the retina remote from the axis, the impression will not be sufficiently strong to form a permanent spectrum, although an object of very moderate brightness will produce this effect when directly viewed. The motion of the eye has a range of about 55 degrees in every direction, so that the field of perfect vision, in succession, is by this motion extended to 110 degrees[1]."

A spot of the retina internal to the axis of vision is found to be originally insensible to light: it is usually supposed to correspond with the extremity of the optic nerve. The experiment by which this phenomenon is shown, is as easily made as it is well known. On repeating it, I verified the following measurements.

Two circular pieces of red sealing-wax each an inch in diameter were fixed upon white paper at the distance of seven inches and a half asunder: having closed the left eye, I drew back from the table, on which the paper was placed at a moderate inclination: when the left-hand object was at the distance of 2 feet 6 inches from the right eye, and directly opposite to it, the right-hand object disappeared. On continuing to retire from the table, as soon as the left-hand spot was 3 feet 8½ inches from the eye the right object reappeared.

Dr. Wollaston has described a partial and temporary insensibility of the retina in both eyes which has twice occurred to himself, and which has directed attention to similar cases. The following are Dr. Wollaston's words.

"It is now more than twenty years since I was first affected with the peculiar state of vision to which I allude, in consequence of violent exercise I had taken for two or three days before. I suddenly found that I could see but half the face of a man whom I met; and it was the same with respect to every object I looked at. In attempting to read the name JOHNSON over a door, I saw only SON; the commencement of the name being wholly obliterated to my view. In this instance the loss of sight was toward my left, and was the same whether I looked with the right eye or the left. This blindness was not so complete as to amount to absolute blackness, but was a shaded darkness without definite outline. The complaint was of short duration, and in about a quarter of an hour might be said to be wholly gone, having receded with a gradual motion from the centre of vision obliquely upwards toward the left.

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[1] Phil. Trans. vol. xci. p. 46.

"Since this defect arose from over fatigue, a cause common to many other nervous affections, I saw no reason to apprehend any return of it, and it passed away without need of remedy, without any further explanation, and without my drawing any useful inference from it.

"It is now about fifteen months since a similar affection occurred again to myself, without my being able to assign any cause whatever, or to connect it with any previous or subsequent indisposition. The blindness was first observed, as before, in looking at the face of a person I met, whose *left* eye was to my sight obliterated. My blindness was in this instance the reverse of the former, being to *my right* (instead of the left) of the spot to which my eyes were directed; so that I have no reason to suppose it in any manner connected with the former affection.

"The new punctum cæcum was situated alike in both eyes, when at an angle of about three degrees from the centre; for when any object was viewed at the distance of about five yards, the point not seen was about ten inches distant from the point actually looked at.

"On this occasion the affection, after having lasted with little alteration for about twenty minutes, was removed suddenly and entirely by the excitement of agreeable news respecting the safe arrival of a friend from a very hazardous enterprise[k]."

Dr. Wollaston with his accustomed sagacity inferred from the symptoms which have been described a peculiarity of structure in the optic nerves, the existence of which has been confirmed by anatomical examination. It has been already mentioned that the outer fibrils of the tractus opticus of one side are continued to form the outer part of the optic nerve of the same side, and that the fibrils next in order pass over to the inner and central part of the opposite nerve: thus the parts of the two retinæ, on which the same part of an object is delineated, appear to be supplied from one nerve.

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[k] Phil. Trans. vol. cxiv. p. 225. In a work upon the anatomy of the nervous system in vertebral animals published by Magendie and Desmoulins, a case is recorded which has great interest in connexion with Dr. Wollaston's narration.

"M. de M—— à la suite d'une fièvre cérébrale, a depuis un mois, le côté externe de la rétine gauche insensible. *De cet* œil il ne voit que les objets situés *à gauche* du centre de vision. Et comme en même temps cet œil a son axe dévié en dehors par une paralysie du nerf de la troisième paire, d'où résulte aussi une procidence de la paupiére superieure, quand il regarde des deux yeux il voit les objets doubles. Mais *ce qui est plus singulier encore* c'est que, l'œil devié étant fermé, la perception de l'œil gauche lui fait voir les objets déplacés de vingt à vingt cinq dégrés à droite de leur position." p. 674.

The point, which is additionally remarked as surprising in this case, is a necessary consequence of the displacement of the eye through the paralysis of the third nerve: the abductor muscle retaining its action is described as having given the axis of the eye a direction outwards; the eyeball may therefore have become displaced something in the same manner as if it had been pressed outwards by the finger applied to the inner canthus. In the latter case objects apparently move with the eye which is moved, and vision with two eyes is rendered double. This phenomenon is reconcileable with or is deducible from the law of vision already explained. What is paradoxical in it is, that although objects are seen in two places at once, they are seen in their real place by both eyes.

The eyes of different animals vary remarkably in their capability of being directed at the same time to the same object. In some again a connexion exists between the two optic nerves, in others the optic nerves are separate, from their origin to their termination. In several species of fish the nerves distinctly cross without intermixture from the thalamus of one side to the eye of the opposite. In birds the optic nerves cohere near their origin; and it has been observed that the degree of blindness, which is produced by opacity of the cornea, is alone sufficient in the space of three weeks to produce wasting and discolouration of the optic nerve, which extends to the tubercle of the opposite side; and conversely, that if the optic tubercle be injured on one side, blindness of the opposite eye immediately ensues. In human beings atrophy of the optic nerve follows blindness very slowly, and the same alteration is not supposed to be continued beyond the commissure. Nevertheless I have witnessed in one instance a discolouration of the optic nerve on one side joined with a similar appearance for a short extent upon the opposite tractus; but the intermediate portion of the commissure was white, and of the previous history of the case nothing was known.

In the preceding details the movements of the eyeball have been occasionally referred to: we may now examine the contrivances provided for this purpose, and the nature of the external parts intended for the protection of the organ of vision.

The optic nerve, of which about an inch is interposed between the foramen opticum and the eyeball, contributes to hold the eye forward towards the front of the orbit. The intervals between the different parts contained in the orbit are filled with adipose substance.

Six muscles are inserted into the sclerotic coat of the eye, of which four are termed recti, and two obliqui.

The recti are thin flat muscles which rise from the margin of the foramen opticum, and extend, one over the upper part, one upon the outside, a third upon the inside of the eyeball, and a fourth below it, to be inserted each by a thin tendon into the sclerotic at about five lines from the edge of the cornea.

The four recti are distinguished individually by the names of, superior, inferior, internus, and externus, with which the terms attollens, deprimens, adducens and abducens, are used synonymously. By careful dissection a layer of membrane may be separated from the part of the sclerotic between the insertion of the recti and the cornea. This membrane is termed the tunica albuginea, and is considered to be the aponeurosis of the recti muscles.

It is easy to understand that these muscles acting singly would direct the eye to four equidistant points in a circle, and acting in concert might turn the axis of the eye towards all the intermediate points: and it is equally obvious that they must exert a constant effort to retract the eye, against which the elasticity of the optic nerve, and the adipose substance in the orbit, would make very inadequate resistance.

The two remaining muscles appear intended to counteract the effect last alluded to.

The obliquus superior or trochlearis rises from the upper and inner part of the margin of the foramen opticum, and advances obliquely forwards and inwards towards the margin of the orbit, where a loop of membrane is attached, through which its tendon passes, and is subsequently reflected downward, backward and outward, to be inserted into the upper part of the eyeball behind its vertical axis.

The obliquus inferior oculi rises from the nasal process of the superior maxillary bone, and passes obliquely outwards and backwards below the eyeball to be inserted into the sclerotic within the rectus externus, and behind the transverse axis of the eye.

The action of the obliqui is involved in some obscurity: there can indeed be no doubt respecting their principal use; by drawing the eye forward they prevent that constant retraction which would otherwise be produced by the recti. But individually they are calculated to give each its specific direction to the eye: the obliquus superior points the optic axis downwards and outwards; the obliquus inferior, on the other hand, directs the eye upwards and outwards.

What renders this question still more intricate, is that three nerves are employed to supply the six muscles that have been described. The fourth nerve supplies the obliquus superior, the sixth supplies the rectus externus, and the third supplies the remaining muscles.

It is remarkable again, that of the six muscles of the eyeball, three turn the optic axis directly or obliquely outward, and that each of these three muscles is supplied from a separate nerve; two indeed having one nerve exclusively distributed to each.

The intricacy of the muscular nerves of the eye admits, however, of a conjectural explanation. We may remark that their distribution is not such as to allow of our opposing the recti to the obliqui: in following this indication we are stopped by the fact that the third nerve supplies half or the greater part of each class. But from the close anatomical relation between the origins of the third nerve and of the fourth, we may conclude *their* function to be not materially different; whereas the sixth nerve rising from a remote point, seems distinguished essentially from both the others.

It appears to be a principle in the construction of the nervous system, that nerves of motion rise near the origin of those sentient nerves, through which the actions they controul are habitually excited.

This principle is remarkably exemplified in all the spinal nerves, and in the distribution of the fifth and seventh cerebral nerves; and the origin of the third and fourth nerves is sufficiently near that of the optic nerve to bring them under the same law. Now when we examine the connexions of the sixth nerve, we find it passing to the back part of the medulla oblongata, and rising near the fifth and the seventh; that is to say, it rises near those nerves which comprehend within their functions the sensibility of the surface of the eye, an influence over the secretion of the lachrymal gland, and the sense of hearing. When again we examine the distribution of the sixth nerve, we find it forming the sole supply of a muscle which has a remarkable consent with the three offices alluded to. The rectus externus or abducens oculi, which it supplies, directs the axis of the eye outwards. And we may remark, 1. that when the optic axis is directed outwards, the surface of the eye is carried towards the orifices of the ducts of the lachrymal gland: 2. that the reversion of the eye for vision is commonly suggested by impressions upon the organ of hearing: and 3. as an instance of the consent between the common feeling of the eye and the action of the abductor, that when an ass is destroyed by pithing, if while imperfect life yet remains in the head the eyelids be rendered incapable of closing by the division of the portio dura, and the surface of the eye be then touched, the motion of the eye to avoid the offending substance is in a direction outwards.

When the eyelids are kept shut, the eyes are commonly in motion: during sleep, as Mr. Bell remarked, the eyes are frequently turned upwards; but sometimes they are directed straight forwards. Whenever I close either eye singly, it is immediately drawn outwards, and upon raising the eyelid, is seen in the act of returning to its place.

Squinting consists in a want of consent between the muscles of the two eyes, through which defect the optic axes are habitually directed towards different points. The inclination of one eye inwards may be so great as to exclude it from the vision of objects towards which the other is turned, or may be so slight as to allow of the distorted eye taking in part of the same field of vision with its fellow. In either case it appears that those who squint, habitually neglect the impressions upon the distorted eye, and see with but one.

The cause of squinting is obscure: for though it frequently happens that the eye which squints has an imperfect vision, so as to favour the supposition that it is instinctively averted in order to prevent the perception of objects becoming confused; yet in other cases, vision with either eye is equally good, and the patient can at will employ either singly, but cannot prevent the other from turning away from the object of vision.

Perhaps in cases of the latter description the original adjustment of the two eyes is not true; so that if both were directed towards the same object, it might necessarily appear double, upon the same principle as in the remarkable case transcribed in a note to page 305.

The parts employed for the protection of the eye are, the eyelids with their muscles, the tunica conjunctiva, and the lacrymal gland.

The eyelids are two folds of skin to which shape and firmness is given by two slips of cartilage termed the tarsi. Upon the surface at which the eyelids meet, the skin is gradually transmuted into a mucous membrane termed the conjunctiva which lines the tarsal cartilages, and is reflected from the inner surface of the eyelids upon the sclerotic coat to cover the front of the eye, the tunica albuginea, and the cornea. The tarsal cartilages have a membranous joint at either corner, from which a ligament extends to the adjoining bone: the ligament on the inside is well defined, and of a bright silvery colour, and is called the tendo oculi; it extends to the nasal process of the superior maxillary bone: the external ligament is broader and of a membranous character; it extends to the frontal process of the malar bone.

The opposite edges of the tarsal cartilages are so grooved and slanted away internally, as to form when they meet a channel, which is closed at the back part by the eyeball. The external edge of this groove is guarded with the strong hairs which form the eyelashes, and upon its inner edge from thirty to forty thin white ducts open, which are termed glands of Meibomeus; they are filled with a white sebaceous or albuminous material. At the inner canthus of the eye the tunica conjunctiva is reflected over a fleshy fold termed the caruncula lacrymalis. The liquid which lubricates the surface of the eye appears raised by this fold of membrane to the apertures of the puncta lacrymalia, as the two capillary tubes are termed, which carry off the liquid from the surface of the eye; they terminate in an oval bag, termed the lacrymal sac, which is lodged in a common fossa of the os unguis and superior maxillary bone, and transmits the tears onwards towards the nose.

The tears form a salt transparent liquid, a hundredth part only of which consists of saline ingredients. Soda and muriate of soda, phosphate of lime, and phosphate of soda, with mucus and water, are the component parts of the tears, according to Fourcroy and Vauquelin. The tears are secreted by the lacrymal gland, a flattened circular body in structure and appearance resembling a salivary gland, which is placed at the outer and upper part of the orbit: its five or six small ducts open at the neighbouring angle of reflection of the tunica conjunctiva from the upper palpebra upon the eyeball.

The lacrymal gland is supplied with two nerves from the first division of the fifth: its secretion is remarkably under the influence of the mind. Yet the surface of the eye does not seem less moist than usual when the fifth nerve has been divided, and it is questionable whether the liquid with which it is generally lubricated be derived from the lacrymal gland or from its mucous covering. The remarkable effect of dividing the fifth nerve upon the nutrition of the eye has been already described: it deserves remark, that the eye is rendered insensible to common stimuli by this operation. Diluted liquor ammoniæ applied to the eye in this state produces no inflammation of its surface,—a phenomenon extremely curious, when viewed in connexion with the fact, that the operation itself produces a violent inflammation of the tunica conjunctiva in twenty-four hours.

When the optic axis is directed forwards, the eyelids meet at the lower margin of the cornea. The lower eyelid has little motion; the upper eyelid alone is concerned in the ordinary opening and shutting of the palpebræ.

The muscle which raises the upper eyelid is termed the levator palpebræ superioris; it rises from the margin of the foramen opticum immediately above the rectus superior oculi, and is inserted into the upper tarsal cartilage: it is supplied by the third nerve.

The muscle which closes the eyelids is called the orbicularis palpebrarum; it is disposed for some breadth beneath the skin of the eyelids in concentric fasciculi. This muscle is supplied by the fifth nerve and by the portio dura of the seventh, and is paralyzed by the division of the latter. The fifth nerve and the seventh rise together: the fifth imparts sensibility to the surface of the eye, to the eyelids and eyelashes; and the least irritation of these parts calls into action the orbicularis palpebrarum, which receives its stimulus through the portio dura of the seventh. If the hand be moved with velocity before the eye at three inches distance from its surface, we are scarcely tempted to close the eyelids; but if it approach so near as sensibly to affect the eyelashes by the displacement of the air, though we are conscious that it threatens no injury, we find it scarcely possible to refrain from the action of winking. The consent between the fifth and the seventh nerve in this instance seems as close as that between the second and the third, or as the connexion between a vivid impression upon the retina and the contraction of the pupil.

SECTION 2.

Of the Organ of Touch.

When the temperature of the media next to us varies considerably from our own, we feel heat or cold; when the pressure of surrounding substances is actually or relatively increased above that which we habitually sustain, we feel the contact of bodies, their hardness, softness, and the like. The preceding modes of sensibility constitute the sense of touch. Parts which enjoy the sense of touch are exquisitively alive to mechanical injury or chemical action.

The skin is the principal seat of touch; but this sense is shared by the mucous surfaces of the eyes and nose and fauces, of the larynx pharynx and œsophagus, of the rectum and urinary canal, and of the external part of the uterine system, as well as by the voluntary muscles.

In some of the latter instances, the eye namely and the larynx, the surface is much more acutely sensible than the skin; but it conveys not the same defined and accurate impression as the skin itself. Different parts of the skin likewise enjoy the sense of touch in different degrees. The hand and fingers, the tips of the latter especially, have practically the finest discrimination of the tangible qualities of bodies; but it is difficult to determine how much of the superiority of the hand in touch may result from the happy flexibility of its joints and the number of its muscles, by which it can vary its form and pressure to suit the nature of different substances.

Sensations of heat and cold are relative; the weather which is mild in winter, appears cold to us in summer. Like other sensations these again essentially depend not merely upon the present impression, but upon the condition of the sentient organ. Thus a patient occasionally feels chilly, when the surface of his body seems to a by-stander more heated than usual. The sensation of cold in the preceding instance is analogous to the perception of flashes of light before the eyes, when an apoplectic attack is threatened.

Custom enables the skin to sustain without inconvenience a degree of heat which naturally gives pain, and even to resist the physical injury, which it commonly produces. Some extraordinary exhibitions have been presented to the public, in which there evidently has been no deception, yet in which the operator has applied heated liquids or heated metals to the skin or tongue, without producing that vesication of the surface which another would have experienced.

It is interesting to trace the order in which the sense of touch may be supposed to communicate to us our first impressions respecting an external world, or to analyze the precise evidence upon which our notions of what are termed the primary qualities of matter are founded.

A sensation of touch resulting from the contact of a foreign substance with the skin communicates a distinct impression of its place. If sensations of touch be excited at different parts of the surface of the body, and continue long enough for the mind to compare them, the notion of an intermediate space, together with the abstract idea of extension, follows. If a foreign substance be moved upon the surface of the body from one point to another, the consciousness we have of its change of place gives origin to the idea of motion. What we term roughness, smoothness, and the like, are sensations produced by moving different substances in contact with the skin.

Branches of the same sentient nerves, which supply the skin, are distributed to voluntary muscles in conjunction with their voluntary nerves: and muscles of this description appear to enjoy in a very high degree a modified sense of touch; a peculiar sensation independent of that referred to the skin is produced by resistance to their efforts. It is from this muscular sense that we immediately derive our notions of the hardness or softness, and of the weight and momentum of bodies.

The something external, which is the cause why sensations occur in us, we call matter. By combining the different sensations, which arise in us on the same occasions, we form our notions of different material substances. We suppose matter to be impenetrable, since we find that two material substances cannot occupy the same place at once. We suppose matter to be infinitely divisible, since we cannot conceive a particle so minute as not to have two surfaces that might admit of separation, —much in the same manner that we suppose space to be infinite, since the imagination can always frame the idea of extension beyond the greatest assignable distance.

The nerves which minister to the sense of touch are the posterior roots of the spinal nerves, the large division of the fifth, the nervi vagi, and the glossopharyngeal nerves.

The body, the neck and occiput, and the limbs are supplied by the spinal nerves; the head and fauces by the fifth; the pharynx and œsophagus by the nervi vagi and glossopharyngeal nerves.

It is remarkable that the nerves of touch have ganglions near their origin. It is to this class of nerves, that physiologists have commonly but vaguely attributed the unconscious influence, which is exercised by the nervous system over nutrition. Recent observation and experiment concur in supporting the justness of this conjecture.

In an interesting case of anæsthesia mentioned by Dr. Yellowly, in which, though sensation was almost wholly extinguished in the fore-arms and hands and in the legs and feet, yet the power of voluntary motion was not much diminished, it was observed that an elevated temperature more readily produced vesication of the skin than in healthy persons; that is to say, the palsy of the nerve which experiment has proved to be the nerve of touch, had deprived the part of its physical capacity of resisting heat.

I have already mentioned M. Magendie's experiments of dividing the fifth nerve in the cranial cavity, both at the ganglion of Gasser and at a part nearer to the brain, and the injurious effect in each case upon the structure of the eye; extending in the former to destructive ulceration, in the latter producing a partial opacity of the cornea only.

What renders these experiments of more than usual value, is the light which they have directly thrown upon pathology and surgery. In my Anatomical Commentaries I have described a case, which was treated by Dr. Macmichael, and which presented the anomalous circumstance of inflammation of the eye combined with palsy of the fifth nerve, that admitted of a satisfactory explanation by reference to Magendie's experiments on animals; and M. Serres has subsequently published a case of a very similar nature, and of the highest interest: for the patient died, and the opportunity was taken to examine the change which had ensued in the fifth nerve. The sentient portion of the fifth together with the ganglion was found discoloured, softened, and loaded with a quantity of serosity; this change extended to the origin of the nerve, and was the more distinct, as it happened that the muscular portion of the fifth was unaffected.

In this case M. Serres observed that in addition to the change produced in the eye (a thickening namely and opacity of the cornea with adhesion of the iris to its surface) other parts had likewise suffered in their texture. The mucous membrane of the tongue was softer and more spongy on the affected side; and though the gums were in a scorbutic state on both sides, yet this appearance was far more marked upon the side which had been insensible [l] [m].

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[l] Medico-chirurgical Trans. vol. iii. p. 94.

[m] Magendie. Journal de Phys. tom. v. p. 248.

SECTION 3.

Of the Organ of Taste.

The organ of taste is situated at the commencement of the digestive canal, and appears originally intended to provide us with the means of distinguishing wholesome food.

The apparent seat of taste is the tongue and palate: the same surfaces have an exquisite sense of touch; and an attentive examination shows that the latter occupies a larger surface than the former, and is indeed the only sense with which the palate is endowed.

Upon the surface of the tongue again the sense of taste is very partially distributed. The mucous membrane which covers it is marked by a vast variety of little elevations. For an inch from its root the tongue is covered with mucous follicles: before these, fourteen or fifteen broad papillæ, termed papillæ conicæ, are found, that are contained in fossulæ, being adherent by their apices and presenting a broad cupped surface level with the dorsum of the tongue; seven of these advance on either side from the centre to the edges of the tongue, the whole remaining surface of which is covered with oval papillæ that proceed in ranks parallel to the papillæ conicæ; these are termed papillæ conoïdeæ: at the edges of the tongue some of similar fabric seemingly to the last assume a shred-like appearance, and are called papillæ filiformes: while a fourth class remains, that are interspersed among the papillæ conoïdeæ; they are termed papillæ fungiformes: the largest of these are found upon the dorsum of the tongue, where they exceed the papillæ conoïdeæ in size; they are smaller but more numerous along the sides and towards the tip of the tongue.

Of these papillæ the last alone belong to taste; they are vascular and erectile, and may be observed to shoot up upon the surface of the tongue, when it is touched by a sapid substance.

In order that a substance may excite a sensation of taste, it must be presented to the tongue in a liquid state: to promote this object, when a solid is placed in the mouth, the saliva is observed to flow abundantly; its sapid qualities are perceived in proportion as it dissolves: in like manner an aëriform fluid is tasted as soon as the moisture of the mouth becomes impregnated with it.

Various substances after exciting the sense of touch on the fauces, and that of taste upon the tongue, are capable of producing a third impression which is popularly referred to the palate, but is really felt upon the sentient membrane of the nostrils: the fume of certain kinds of food ascends into the cavities of the nose, and produces a third and distinct sensation: in administering medicine to children, it is well known that the greater part of what is disagreeable in its flavour may be avoided, by closing the nostrils while the draught is swallowed: and by repeating this experiment upon various articles of food, it is easy to ascertain how much of their flavour depends upon one sense, and how much is appreciated by the other. Hence it is that the senses of taste and smell have been often compared as having a resemblance, the odour of many substances being supposed to resemble their flavour; while the fact is, that the flavour of such bodies consists in their scent, and that the two impressions, which are compared, are identical.

It follows from what has been said that substances taken into the fauces may be such as either,

1. to excite sensations of touch alone; of this nature are rock-crystal, sapphire, or ice:

2. or to be felt upon the tongue, and in addition to excite sensation in the nostrils, as for instance tin and other odorous metals:

3. or to be felt upon the tongue, and in addition to excite sensations of taste, as for instance sugar and salt:

4. or finally, to be felt upon the tongue, to be tasted by the tongue, and in addition to excite sensation in the nostrils, as for instance bread, manna, and other substances.

It may be remarked in addition that some substances of a penetrating nature, such as peppermint, appear to produce another distinct impression, the seat of which seems to be the pharynx.

Sensations of taste are not perfect, until the mouth is closed and the tongue pressed against the palate, by which means the sapid liquid is brought into more exact contact with the surface of the tongue and perhaps forced into the texture of its mucous membrane, at the same time that its fumes are driven through the posterior fauces into the cavities of the nostrils.

The tongue is supplied, by the ninth nerve, which is distributed through its muscular texture: by the gustatory, a branch of the ganglionic portion of the third division of the fifth, which is distributed not merely to the muscles of the tongue, but to its mucous surface likewise and to two of the salivary glands: by the glossopharyngeal nerve, which gives branches to the surface of the root of the tongue.

After the division of the ninth nerve on both sides in dogs and rabbits, the tongue loses the power of motion, so that, when a little drawn out of the mouth it remains protruded, and is not retracted when acrid substances are applied to it; which yet evidently produce the usual degree of sensation.

Upon dividing the gustatory nerve the tongue loses sensation, but its muscles appear to retain their tone.

Upon pinching the gustatory nerve in animals immediately after death, no movement follows of the fibres of the tongue: but each time that the ninth nerve is pinched, the muscles of the tongue are convulsed.

In a case in which the symptoms present showed that every portion of the fifth had lost its influence, the peculiar sensibility of the root of the tongue remained; a vague sensation of touch, attended with a momentary nausea and effort to vomit, ensued as in healthy persons upon pressing the surface of the root of the tongue with a probe. Upon pinching the glossopharyngeal nerve in animals immediately after death, no spasm follows of the muscles of the tongue.

SECTION 4.

Of the Organ of Smell.

Particles are continually flying off from the surfaces of bodies: the air seems to dissolve infinitely minute portions of every substance with which it is in contact. Hence arise the virtues of salubrious situations, or the poisonous qualities of such as are noxious; the atmosphere becoming impregnated with the elements of the soil in proportions too delicate to be tested except by the animal frame, into which they find admission through pulmonary absorption. The atmospheric solution of many substances is distinguishable by the sense of smell. The organ of this sense forms the commencement of the respiratory tube, so that each time we breathe, the olfacient qualities of surrounding substances are submitted to our senses.

The sense of smell is calculated to give warning of the vicinity of unwholesome objects, and to minister to the appetites; or like the sense of hearing may be employed to furnish a succession of impressions that are merely grateful. The influence of this sense over the frame is very remarkable: one odour will instantly produce loathing, nausea, and vomiting; another, like the pleasant fragrance of the country on a spring morning, has a part in producing an exhilarating influence upon the mind.

The organ of smell is separated into two chambers, by a partition, which is seldom exactly in the median plane of the head. This partition consists of the nasal processes of the ethmoïd and sphenoïd bones, of the vomer, and of the cartilago septi narium. The floor of each chamber or nostril is formed by the superior maxillary and palate bones. The outside by the superior maxillary bone, the palate bone, the os unguis, the os planum, the cartilago nasi lateralis, and the cartilago alæ nasi. The floor of the nostril is horizontal and slightly hollowed, the septum nearly vertical and plane: at the upper part is the narrow cribriform plate of the ethmoïd bone, upon the outside of which the inferior cornu of the ethmoïd bone, and the inferior turbinated bone fall like curtains, leaving a triple passage toward the pharynx. The frontal sinuses open through the anterior cells of the ethmoïd bone into the middle meatus of the nostrils:

the sphenoïd cells and the antrum of Highmore open through the posterior cells of the ethmoïd bone into the superior meatus. The lacrymal duct opens into the inferior meatus.

The thick and vascular mucous membrane, which invests this extensive surface of bone and cartilage, is termed the Schneiderian membrane. Over the whole of it are distributed branches of the fifth; upon the fore part, a branch from the nasal portion of the first division of the fifth; upon the remaining surface, branches derived from the ganglion of Meckel. The distribution of the first nerve is more limited. The first nerve enlarges into an oval bulb, containing grey matter, upon the lamina cribrosa of the ethmoïd bone, which it perforates in numerous filaments, that are spread over the septum narium and the outer surface of the upper turbinated bone only.

The simple contact of an atmosphere laden with odours is not sufficient to produce sensation in the nostrils. In order that smelling may take place, it is necessary that air impregnated with the odour be carried with some momentum against the surface of the Schneiderian membrane.

The upper part of the nostril again appears to be the region, to which the sense of smell is limited, or at which it is most exquisite. The apertures of the nostrils, and the inclination of the nose are obviously adapted to direct the stream of air in that direction. Accordingly when the nose has been destroyed by disease, smell is found to be greatly impaired or lost.

It is usual and reasonable to suppose the first nerve to be that employed in the sense of smelling. The nostrils are the only parts which distinguish odours, and though two nerves are distributed upon their sentient surface, yet one alone has its distribution confined to this organ. The acute sense of touch which the nostrils enjoy in addition seems a sufficient use for the remaining nerves which are spread upon the Schneiderian membrane: they are one and all derived from trunks, all the other branches of which are nerves of common feeling.

M. Magendie has recently tried the effect of the separate division of the first and fifth nerve in animals: and has thus more precisely pointed out, how much of the impression received upon the nostrils belongs to smell properly so called, and how much to touch. It appears that upon the division of the first nerve the animal remains as sensible to the disagreeable impression of odours which act pungently as before: a young dog thus mutilated appeared conscious of an unpleasant impression when ammonia, acetic acid, oil of lavender, or Dippel's oil were held to its nose: on the other hand after the division of the fifth, the first nerve remaining entire, an animal is not affected by the presence of the substances above mentioned. But M. Magendie mentions, that a dog, which survived the division of the fifth nerves for a considerable period, would at times, when food was offered to it rolled up in paper, unroll the paper, and expose and eat the food; although at other times he appeared to want the power of distinguishing by smelling the presence of objects placed near to it[n].

Pungent odours seem to offend the nose upon the same principle that they irritate the conjunctiva of the eye; their acrid impression, without their scent, being perceived, when the influence of the first nerve is artificially destroyed: such at least appears to be the inference justly deducible from the facts which M. Magendie has added to our knowledge upon this subject, and which leave the first pair of nerves in full possession of the faculty of smelling.

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[n] Magendie. Journal de Phys. Exper. vol. iv. p. 173.

SECTION 5.

Of the Organ of Hearing.

The physical impression upon the organ of hearing, which produces sensations of sound, is not the impingement of a peculiar substance on the nerve, nor the simple contact or pressure of solid or liquid substances, but consists in an impulse which bodies appear capable of transmitting in proportion as they are capable of vibrating. Continued sound is always attended with sensible vibration; the furniture in a room is observed to shake as a carriage rolls by upon the pavement; the finger wetted and carried round the rim of a water glass produces a musical note, and the rippled surface of the fluid as well as the sensation communicated to the hand shows that the glass is vibrating.

The impulse, which produces sound, is transmitted more rapidly through solids than through liquids, by liquids than by aëriform fluids. Sound travels through air with a velocity of 1130 feet per second, and it is calculated that it would be transmitted through water with a velocity of 4900 feet, through wood with a velocity of 12,000 feet per second.

Sound transmitted through a fluid spreads in every direction like the impulse communicated to water when a stone is thrown into it. Hence it may be understood how sound, when moving through a fluid is diminished in intensity (like light) in the ratio of the square of the distance. Sound likewise admits of being reflected like a wave of water: upon this principle depends its concentration by means of the speaking or hearing trumpet. Sound is deadened by passing from one medium to another. Sound perishes when no material substance fit for its transmission is present. A bell struck in an exhausted receiver is scarcely audible.

The essential part of the organ of hearing consists of a series of cavities, termed the labyrinth, hollowed in the petrous bone, that are lined with a membrane containing a liquid, in contact with which the portio mollis of the seventh nerve is expanded.

The labyrinth is divided into the vestibule, concha, and semicircular canals, a particular description of which would be superfluous, as the specific advantages resulting from their shape is unknown. But it is to be remarked that a provision is made for the free vibration of the fluid which they contain by means of two apertures, the fenestra rotunda and fenestra ovalis, that are closed by a membrane only.

As long as the labyrinth is perfect, no degree of obstruction of the external passages or removal of the external parts can prevent hearing from taking place. In a total obstruction of the external passages sound may still be conveyed through the bones of the head to the auditory nerve, as for instance when a tuning-fork is held by the teeth; and thus in deafness an accurate criterion is furnished to determine whether the disease be seated in the labyrinth or in the passages leading to it. In a total loss of the external parts on the other hand, sound is capable of being communicated through the air to the membranes and liquid of the labyrinth, if they remain entire, nearly as perfectly, it should seem, as when the outer parts are complete[o].

The chambers of the ear external to the labyrinth are the cavity of the tympanum and the meatus auditorius externus.

The tympanum is a narrow chamber, which opens forward into the posterior fauces through the Eustachian tube, and is continued backwards into the cells of the mastoïd process of the temporal bone. The membranes of the fenestra ovalis and fenestra rotunda prevent communication between the cavities of the tympanum and of the labyrinth. The membrana tympani on the opposite side is interposed between the tympanum and the meatus auditorius externus. A chain of bones, the malleus, the incus, the os orbiculare, and the stapes, extend from the membrana tympani to the membrana fenestræ ovalis; and four little muscles, the tensor tympani, the laxator tympani, the externus mallei, and the stapedius, by drawing upon the ossicula auditus, give greater or less tension to the membranes, which those bones unite.

The membrana tympani is very vascular, but presents a dry shining cuticular surface. It appears to contain fibres that converge towards its centre; which part is drawn inwards, and has attached to it the handle of the malleus. It is worthy of remark that the ossicula with their muscles are situated to the inside of the *upper* half of the membrana tympani, or are placed at the upper part of the cavity of the tympanum: the practical application of this fact is the following.

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[o] It is to be observed that the stapes is so strictly applied to the membrana fenestræ ovalis, that the loss of this bone necessarily produces incurable deafness by injuring the labyrinth.

One sort of deafness to sounds transmitted in the common way results from an obstruction of the Eustachian tube: when this happens through any cause, the air confined in the cavity of the tympanum cannot vibrate, and therefore cannot transmit sound. An obstruction of the Eustachian tube is supposed to exist, when those sounds alone are heard, that are transmitted through the bones of the head, at the same time that the meatus auditorius externus appears perfectly free, and that the patient is unable to inflate the tympanum by impelling air into it from the fauces. As long as the Eustachian tube remains obstructed, and the membrana tympani perfect, the vibrations of sound are in vain transmitted along the outer passage: the ossicula auditus form an insufficient medium of communication between the membrana tympani and the membranes of the labyrinth: and hearing is only restored by the operation of perforating the membrana tympani.

The meatus auditorius externus with the addition of the cartilaginous part is an inch in length: it is curved in every sense like an italic *f*, its general direction is horizontally outwards and backwards. This canal is fenced with short strong hairs, and its surface secretes a peculiar substance termed cerumen, which is of an orange yellow colour and bitter taste, consisting of albumen, an inspissated oil, colouring matter, soda, and phosphate of lime[p]. The cerumen is liable to collect in thick inspissated masses, sufficient to obstruct the passage of sound along the meatus auditorius externus.

The external ear is formed of an expansion of the cartilage, which forms the outer half of the external meatus: its several folds and margins are distinguished by separate names: the helix is the outer folded edge; the antihelix is the fold parallel to the former: the deep hollow below and before the antihelix is called the concha, the anterior edge of which is formed by the fold termed the tragus, the posterior edge by the antitragus. The attollens, the retrahentes, and the anterior auris are muscles which carry the outward ear in the directions, which their names specify. The helicis major and minor, the tragicus and antitragicus, and the transversus auris, are thin muscular slips, which extend from one point to another of the external ear, and are calculated to expand the different hollows and fossulæ into which the surface of the ear is thrown. Among savage tribes the outward ear is prominent, and moveable like the ears of animals; their hearing is more acute than that of civilized nations, and it is probable that the motions of the external ear assist them in discriminating the direction and nature of different sounds.

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[p] Thomson's Chemistry, vol. iv. p. 513.

The portio mollis of the seventh nerve we may infer from its distribution to be the nerve of hearing. The portio dura of the seventh traverses a canal in the temporal bone: it is joined in its course by a branch from the second division of the fifth nerve, and from the united trunk filaments are given to the muscles within the tympanum. But the portio dura is a nerve of voluntary motion, and the second division of the fifth is a sentient nerve; thus the circuitous route of the portio dura and its junction with the Vidian nerve are explained. The division of the trunk of the fifth nerve in cats within the cranial cavity does not seemingly affect the acuteness of hearing on the same side.

CHAPTER XIII.

OF THE HUMAN VOICE.

IN order to elucidate the origin of vocal sounds it is necessary to go back again to the nature of sound in general, to consider its principal modifications, and the different methods by which it is produced.

A single impulse communicated to an elastic body, produces a noise; a succession of impulses, following each other too rapidly to be separately distinguished, produces a continued sound; and if they are equal among themselves in duration, they produce a musical or equable sound. Thus a quill striking against a piece of wood causes a noise; but striking against the teeth of a wheel or of a comb, a continued sound; and if the teeth of a wheel are at equal distances, and the velocity of the motion is constant, a musical note[a].

In the greater number of musical instruments sound is produced by throwing into vibration either a tense chord, or a column of air; and the tone or note produced is found to be raised when the chord or the column of air is rendered shorter, and deepened, when the reverse happens.

The organ, in which the tones of the human voice are formed, may be compared to the flute or more appropriately to the clarinette and similar instruments; it consists of a mouth-piece, the aperture of which is capable of being expanded or dilated, and of a tube which admits of being lengthened and shortened.

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[a] Young's Lectures.

This organ is termed the larynx; the tube, which composes it, is placed upon the upper part of the trachea, so that as the air issues during expiration, it may cause the edges of the aperture through which it re-enters the larynx to vibrate.

If the upper part of the trachea be divided, on looking into the larynx from below, the tube from being cylindrical is seen to assume abruptly a triangular form. The two long sides of this triangle, extend horizontally inwards and forwards to meet at the front of the larynx. The base of the triangular opening is short, and has a transverse direction. The opening is termed the rima glottidis. The two long edges which meet at the fore part are termed the chordæ vocales.

When we look into the larynx from above, we notice, the epiglottis, a thin flap of fibrous cartilage, held vertically by its elastic connexions against the root of the tongue, but capable of being thrown down to cover the opening of the glottis; the lips of the glottis, or the reflexion of the mucous membrane from the edges of the epiglottis to the posterior margin of the larynx; and the ventriculus laryngis, as the shallow fossa is termed, situated immediately above and to the outside of the chordæ vocales, which allows these parts to vibrate freely.

If an incision be made in a living dog immediately below the cornu of the os hyoïdes, so as to expose the cavity of the larynx, the following phenomena are observable.

At each expiration, the rima glottidis is narrowed, and the chordæ vocales are brought nearer to each other, so as to come in contact for part of their length.

When the animal cries, the chordæ vocales appear to vibrate.

When the tone uttered is grave, the chordæ vocales seem to vibrate for their whole length, and the rima glottidis is proportionately larger.

When the animal utters a shrill cry, the rima glottidis is observed to become much narrower; and the chordæ vocales being in contact at their fore part, a portion only of each appears to vibrate.

The rima glottidis is the mouth-piece of the larynx, and corresponds with the reed in the clarinette, or with the lips of one playing upon the flute;—if indeed either of these comparisons be strictly just.

In pursuing the same similitude we look for a contrivance analogous to the stops in the flute or clarinette, by means of which the tube may be shortened or lengthened; and we find the effect we anticipate produced by the alternate rising and falling of the larynx. When the larynx is raised the vocal tube is shortened, when it is depressed the vocal tube is lengthened. Accordingly, when we utter an acute note, the larynx suddenly rises; and sinks, when the voice falls to a grave tone.

In either of the three cases, the flute, the clarinette, the larynx, the force with which the air is impelled into the instrument consists in the action of the muscles of the chest, that are employed in expiration. But as in playing upon wind instruments, the force of the air may be increased by the action of the muscles of the cheeks, which straighten the channel through which the air passes, so possibly in modifying the tones of the human voice, a similar effect may be produced by the contraction of the transverse muscular fibres of the trachea.

The use of the epiglottis according to Magendie is to perfect the larynx as a musical instrument. It seems that in the clarinette a note swelled beyond a certain degree of loudness is liable to break into a higher note; now M. Grenié discovered that by placing a tongue of elastic substance to break the current of air, this imperfection is remedied. But the epiglottis is just such a contrivance in the vocal organ; the use of which was unknown, till accident thus discovered it.

We have now to raise the curtain, and to examine the mechanism by which the changes are produced, in the place of the larynx and in the size of the rima glottidis, which have been described.

The same muscles, that are employed to raise the pharynx in deglutition, are used to elevate the larynx in modifying the tone of the voice. This action for either purpose is primarily instinctive; afterwards we repeat at pleasure an effort, which we recollect was attended with a result which pleased us.

Other smaller muscles, which extend from point to point of the cartilages of the larynx, alter the dimensions of the rima glottidis.

The principal piece in the structure of the larynx is the cricoïd cartilage, a thick ring rising behind to the height of an inch: it is received between the two flat plates of which the thyreoïd cartilage consists: and upon its raised posterior margin, two little pyramids of fibrous cartilage, called the arytænoïd cartilages, are loosely articulated so as to move freely.

The edge of the chordæ vocales appears formed of a peculiar elastic substance, extending from the front of each arytænoïd cartilage to the thyreoïd, so that any movement given to the former immediately affects the dimensions of the rima glottidis.

Muscles termed crico-arytænoïdei postici and laterales extend from the back and outer part of the cricoïd cartilage to the arytænoïd of each side, and in their action draw the two apart from each other, and enlarge the rima glottidis.

Another broad but thin muscle termed the thyreo-arytænoïdeus extends from the arytænoïd cartilage to the thyreoïd. This muscle is parallel to the chorda vocalis of the same side, and enters into its composition.

The three preceding muscles are supplied by the recurrent nerve, a branch of the nervus vagus: upon its division animals lose their voice.

It is easy to account for this phenomenon by reference to the anatomical facts, which have been mentioned: when the muscles, which the recurrent nerve supplies, act together, the chordæ vocales are thrown into a state of tension; if the crico-arytænoïdei are stimulated to contract more forcibly than the thyreo-arytænoidei, the aperture of the rima glottidis is capacious and fitted for the production of grave notes: if the thyreo-arytænoïdei on the other hand act the most forcibly, the chordæ vocales must be drawn near to each other, and coming into contact at their fore part through the swelling of the shortening muscles which enter into their composition, are at liberty to vibrate in part only of their length.

Another set of small muscles is found at the upper part of the larynx; the arytænoïdeus transversus and the arytænoïdei obliqui extend across from one arytænoïd cartilage to another, and in their action draw these parts together, and entirely close the aperture of the glottis; these muscles, with the mucous membrane, which invests them and clothes the adjoining surface of the larynx, are supplied by separate branches of the nervus vagus, termed the superior laryngeal nerves: and though it is probable that their action in some degree influences the voice, yet they are principally concerned in other functions of the larynx, which have been already alluded to and may on the present occasion be fully explained.

The larynx is the guard of the respiratory apparatus during deglutition: when the food passes over its aperture, the muscles last described instinctively close it. When the nerve which supplies them is divided on both sides, deglutition can no longer take place perfectly, but each attempt at swallowing is attended with the entrance of some of the food into the trachea, which is immediately expelled by violent coughing, the sudden action of the expiratory muscles, which drives out the offending substance before the torrent of air, that is expelled.

The larynx again is intended to prevent the entrance of noxious substances into the lungs: for this purpose the mucous surface of the larynx is endowed with acute sensibility, and the instinctive operation of its muscles is so prompt and powerful as to oppose successfully every effort at inspiration, when an animal is immersed in fluids, the inhalation of which would be prejudicial: when an animal is placed in a vessel containing carbonic acid, its attempts to inspire are useless.

A frequent kind of disorder in parts thus endowed is an increased susceptibility of the sentient surface, and a tendency to spasmodic action in the adjacent muscles, which usually act from impressions received upon it. Thus in the urethra, a morbidly sensible state of a part of the mucous membrane produces spasmodic stricture, or a continued contraction of the surrounding fibres of the accelerator urinæ. In the present instance the consequences are more fatal, in proportion as the function impaired is more immediately important to life. An ulcer within the larynx is not a very uncommon occurrence: when this complaint exists, the whole surface of the larynx occasionally becomes acutely sensible; the air passing over it is now an irritant, the fibres which close the opening of the larynx forcibly contract, the patient cannot draw his breath, and is threatened with instant suffocation. In hydrophobia again the portentous symptom, whence the name of the disease is derived, springs from a like cause. The surface of the larynx is præternaturally sensible (or is the principal seat of that morbid sensibility which is shared by every sentient organ in this disease); the passage of food, of liquid especially, the contact of which is more perfect than that of solid food, excites a spasm which threatens suffocation; and even if swallowing be not attempted, a paroxysm threatening suffocation takes place at intervals, either from the mere contact of the air passing over the sensible surface of the larynx, or in consequence of some sudden impression being made on another organ. The nature of the phenomenon last mentioned, the spasm namely of the glottis brought on in hydrophobia by any sudden impression, perhaps admits of being illustrated by a circumstance of which every one must have had experience. In plunging the feet into water at a low temperature, the disagreeable impression of coldness, which ensues, is attended with a painful sense of constriction at the glottis. The same physical connexion seems to operate in the two instances.

It deserves to be remarked, that whenever suffocation is threatened by a spasm upon the glottis, that particular symptom admits of relief by opening the windpipe; but no doubt in many instances, and hydrophobia is probably one of them, the disease would prove not the less rapidly fatal, were the spasm upon the larynx thus alleviated.

We may wonder that muscular fasciculi so slight as the arytænoïdei obliqui and the transversus, however advantageously placed, should be capable of counteracting the efforts of the diaphragm and other muscles of inspiration. But they are found to be no less efficient against the muscles of expiration. According to the experiments of Mr. Bourdon, an animal cannot leap or swim or even vomit easily, if it be made to breathe through a tube introduced into the trachea. In the muscular fibres, which close the larynx, Nature has provided the means of rendering the parts of the thorax immoveable, so that the action of muscles which arise from the ribs may be made to tell at pleasure upon their opposite attachments alone.

To return from this digression to the subject of the human voice:—We have now seen in what manner its tones are produced: their loudness results from the force with which the air is expelled from the chest. The intensity of sound depends upon the extent of the vibrations of the chord which produces it. The air issuing from the lungs with greater force than usual throws the chordæ vocales into broader vibrations. Thus persons in vigorous health speak in a firm steady voice, whereas in the weakness that illness produces, the tones are scarcely raised above a whisper.

The difference in the tones of the voice in the two sexes, and in the male sex before and after puberty, results from a difference in the size of the vocal organ. At the age of puberty in the latter instance the larynx greatly enlarges, and the lengthened chordæ vocales become capable of producing the deep tones of manhood.

We seek in vain in the structure and natural endowments of the vocal organs for the cause of the limitation of speech to human beings. All that nature instinctively leads us to utter appear to be some vague and wild cries, with scarcely more compass and variety than those of animals; they are characteristic of strong emotion, and when heard seem, independently of association, to affect us powerfully with sympathetic feelings.

But with organs naturally flexible, and with a tendency to express by signs what is passing in his mind, it is not surprising that language should have been one of the earliest inventions of man. Instinct would have led our first parents to the use of their vocal organs; and curiosity and the tendency to imitate would have soon developed their compass. When we fancifully endeavour to conceive the origin of language, we may plausibly suppose that the earliest words employed were sounds denoting different sensible objects in nature. Accordingly in Genesis we find it narrated that the animals presented themselves before Adam, and were named by him. It is easy to imagine that as fast as thought improved, the rude language which expressed it would become extended likewise. Upon this principle the language of a nation becomes a certain evidence of the intellectual refinement, which it has at one time or another attained.

Language is probably the only invention which has been perfected by use, without reference to scientific principles. Philosophy has been employed in this instance (as upon the works of nature), in enucleating only the common principles, and in tracing the analogies, which pervade its structure. But physiology has nothing to do with the philosophy of language; or its connexion with this subject is limited to the illustration of the means, by which articulate speech is produced, or by which vocal sounds are framed into syllables. As sound passes through the fauces it takes a character from the shape into which they are temporarily thrown: each letter or elementary sound has its special mode of articulation. But though it might seem trifling to describe the precise manner in which each letter is formed, let me remark nevertheless that this subject is not entirely devoid of a practical application. Some persons are unable to pronounce particular letters: in most cases this happens from not knowing how to set about it; for if those who labour under such a deficiency are told exactly by what motion of the parts the letter is to be sounded, they often readily master the difficulty, which before seemed insuperable.

To close this subject with a paradox, let me observe that notwithstanding what has been said of the parts concerned in speech, human beings are capable of articulating without a note being formed in the larynx, and even without any apparent movement of the lips or of the jaws. The first case happens when we whisper; no tone is then formed in the larynx; and what we articulate is but the rustling sound produced by the air passing over its relaxed and unstrung surface. The second case constitutes ventriloquism.

A ventriloquist is a person of very flexible vocal organs, who is able to articulate most sounds by changes produced in the form of the posterior fauces, and who has readiness enough to avoid in the display of his art those letters, which absolutely require the motion of the lips, and sufficient fineness of ear to modulate his tones to that character which they would take in the situation from which they appear to proceed.

CHAPTER XIV.

ON THE ATTITUDES AND MOVEMENTS OF MAN.

In explaining the functions of the heart and lungs, the disposition of the bones of the chest was described, and on the same occasion and on others, I have had to advert to the action of different classes of voluntary muscles. We have now to consider the entire frame of the skeleton in reference to the postures and movements of the body, and the action of the voluntary muscles of the trunk and limbs. Let us begin with an examination of the structure and chemical composition of bone.

Upon making sections of a dry bone, we find it composed of two parts; externally, of a compact crust of greater or less thickness, and internally, of a series of delicate plates and processes that intercept innumerable small cells or cancelli, which freely communicate.

The bones of the skeleton affect three principal forms; each of which has some peculiarity in its structure adapted to the object upon which it is employed.

The flat bones are those which belong to the great visceral cavities, the cranium, the chest, the pelvis. In these bones the outer crust is thin, and forms what are termed tables, the outer and the inner: the interposed cancellated structure is termed the diploe. The two tables of the flat bones are for the most part parallel. In the skull the inner table is of a closer grain and of greater density than the outer. The external surface of flat bones is generally convex, a circumstance which contributes with the alternating compactness and porousness of their texture to protect the parts within against any kind of injury.

The round or cuboïd bones are small irregular cubes or portions of cylinders, one series of which forms the vertebral column, another the wrist, and a third the instep: their crust is yet thinner than that of the flat bones; their internal structure varies in different instances: the cancelli are fine in the vertebræ; coarse in the tarsal and carpal bones. The texture of cuboïd bones is therefore any thing but brittle, and is well calculated to deaden the force of jars and concussions of all sorts. To promote the latter object, the cuboïd bones are found not separate but in groups, so that the elasticity, resulting from many joints and intervening layers of cartilage, gives additional effect to their structure. Another advantage results from forming the parts described of many bones; a considerable latitude of motion may thus exist in the entire part, and at the same time no single joint have play enough to risk its security.

The long or cylindrical bones are employed as levers upon which the muscles act in supporting and impelling the body. The extremities of a cylindrical bone, where it is articulated to those adjoining, as they have the office, so likewise have they the structure of the cuboïd bones, a thin outer crust, and strong cancelli: they likewise generally assume a considerable breadth, which increases the strength of the joints.

But the intermediate part or shaft of a long bone is contrived differently; its crust is of great thickness, from $\frac{1}{4}$ to $\frac{1}{3}$ of an inch; while the plates belonging to its cancelli are remarkably fine and delicate. The bony matter, spread out in thin and separate plates in the extremities, seems collected in the shaft to form a compact cylinder, in order that the lever which it represents may not be flexible; and the cylinder is hollow, to give the greatest strength to a determinate weight of bony substance.

If a bone be calcined, the earth which remains has the same form and structure as before; but it is rendered brittle, and falls in pieces almost from its own weight. If a bone be steeped in acid, it retains its form and structure, but becomes perfectly flexible.

The following table exhibits the composition of calcined human bones according to the analysis of Berzelius.

Phosphate of lime	81.9
Fluate of lime	3.0
Lime	10.0
Phosphate of magnesia	1.1
Soda	2.0
Carbonic acid	2.0
	100.0

Recent bones are covered with a membrane termed their external periosteum, which is easily detached from their surface; it is thin, except where tendons or ligaments are inserted. All the cavities in a bone again are lined with a fine membrane termed the internal periosteum; from its surface is secreted the marrow or animal oil which fills the cancelli. Upon examining the bones in a favourable subject minutely injected with size and vermilion, blood-vessels may be traced through their entire substance. Neither lymphatics nor nerves have been followed into bone; but absorption evidently takes place during the growth of bone, and if a young animal be fed with madder, in six weeks time red earthy matter seems substituted in the place of white earth in all its bones. During health bones do not appear sensible to any stimulus: during disease they exhibit acute sensibility.

The modes, in which the bones of the skeleton are joined together, are very various; in some instances no motion is allowed between adjoining bones, and they seem to have been left disunited with the object only of diminishing the effect of concussion. The bones of the head are thus disunited or united through the intervention of membranous substance only. In parts of the cranium where strength is required, the bones are dovetailed together, and the joint is called a suture: in other instances the bones meet at an even line, which is termed union by harmonia, or if a process of one bone is received into a corresponding cavity in another, the juncture is termed schindylesis, or gomphosis.

In other instances, where no motion is intended to take place, but where a part has often to resist considerable violence, a portion of white elastic substance termed fibrous cartilage is interposed between two bones, with the extremities of either of which it is continuous; in this manner the ossa innominata and sacrum are joined together. As a variety in this sort of articulation we may remark that the true ribs are joined to the sternum by portions of fibrous cartilage, which are received into sockets at the side of the breast-bone, but are not continuous with it, if we except the first: a layer of membrane is interposed between the cartilages of the other ribs and the breast-bone, so as to allow of the requisite motion at the sterno-costal joints during the dilatation of the chest.

In the kind of joint last described another substance called a ligament is generally found in addition. Ligaments are white silvery bands composed of very delicate fibres, that, where they are flexible, have but little elasticity except in a few instances: they are composed nearly wholly of gelatin; they have little sensibility to common stimuli, but when stretched feel acute pain.

The junction of the bodies of the vertebræ deserves to be particularly described. In fish, in which the spine is very flexible, the articular surfaces of the bodies of the vertebræ are so excavated, that when two meet they inclose a cavity the shape of which may be called spherical: this cavity is filled with fluid, which we will suppose to be incompressible, and the margins of the two vertebræ are joined together by the intervention of ligamentous substance, which is highly elastic; thus a double ball and socket joint exists between every two vertebræ, each of which is capable of rolling in every sense upon the ball of liquid contained between the two. In the human spine the same type is followed, but with a provision for much less latitude of motion; the excavation is shallow, the central substance semifluid, and the surrounding fibrous cartilage is confined by ligamentous bands of less elastic substance.

In the more elaborate joints two other elements are met with. The articular extremities of the bones are tipped with cartilage, and a fine membrane is reflected over its surface and over that of the capsular ligament by which the bones are joined together. Membranes of this description in many respects resemble serous membranes: they form shut sacs of the finest texture, and can be separated though not without difficulty from the ligaments and periosteum, which they cover: but they scarcely admit of being detached from the surface of cartilages. I have one preparation, however, in which I accidentally succeeded in raising an uniform membrane from the cartilage covering the head of the humerus. Membranes of this description take their name from the viscid fluid called sinovia, which they secrete, and which lubricates the internal surfaces of joints.

From an analysis by M. Margueron it appears that sinovia is composed of the following ingredients:

Fibrous matter	11.86
Albumen	4.52
Muriate of soda	1.75
Soda	0.71
Phosphate of lime	0.70
Water	80.46
	100.00

Joints which combine these various elements are distinguished into different classes according to the form which they affect, and the kind of motion of which they allow.

A ball and socket joint, or enarthrosis, like the hip, gives great security, and at the same time permits very extensive motion.

A joint, in which surfaces nearly plane are opposed to each other, is termed an arthrodia; the motion allowed in such a case is very limited, but takes place in a degree in every sense.

A joint which allows of motion in one plane only is termed a ginglymus or hinge joint. Of this joint there are two kinds; in one the motion is angular, as in the knee, or rotatory as between the atlas and dentata.

Such are the materials of the skeleton, and the different modes in which they are joined together to form one frame.

When we seek in the skeleton for illustrations of that analogical design, which is evident not merely in entire classes but in single objects of nature's workmanship, we remark that the head is not a part which corresponds with any subdivision of the frame, but rather seems an epitome of all the rest. Thus the embryo when first seen consists of two coherent nodules not differing materially in volume even, one of which becomes the head, while the other spreads into the trunk and limbs.

When we compare together the several regions of the trunk, we observe that it is laid out in corresponding organs on either side of a centre, which consists of the five lumbar vertebræ. Above the lumbar vertebræ are the dorsal vertebræ, above these the cervical; below the lumbar vertebræ are the sacral bones, below these the coccygeal. To the dorsal vertebræ and to the sacrum bones are articulated, which have the double office of forming a visceral cavity, and of throwing to a convenient distance from the median plane the bones of the extremities. The ribs and sternum, the clavicle and scapula form with the dorsal vertebræ an organ strictly analogous to that formed by the ossa innominata and the sacrum. But the chest for the function of respiration requires to be continually altering its dimensions, and the upper extremity is characterized by the extent and velocity rather than by the strength of its motions: to suit both these objects, the chest and shoulder are formed of many bones, that are moveable in various senses; the ribs are capable of rotating upon their sternal and vertebral joints, and of being raised or depressed upon their vertebral joints carrying with them the sternum; the clavicle again revolves upon the sternum, and the scapula rolls upon the convexity formed by the angles and shafts of the ribs. On the other hand the pelvis, as regards the viscera, is intended merely for their support, or if during labour a temporary enlargement of its lower aperture be requisite, the flexibility of the joints of the os coccygis in the female skeleton seems a sufficient provision for this object: the inferior extremities again require to be articulated to a solid unyielding platform, upon which they may poise the incumbent weight of the trunk and head. The bones of the pelvis are for these reasons, few, weighty, massive, and knit together immoveably. Thus accurately do the points, in which a resemblance is wanting between the chest and pelvis, preserve the analogy between these parts.

It is needless to dilate upon the correspondence of the femur with the humerus, of the tibia, patella and fibula with the radius and ulna, of the tarsus with the carpus, of the bones of the foot with those of the hand. As mobility is the prevailing character of the upper extremity, the radius plays upon the ulna, the bones of the wrist are so disposed as to form three ball and socket joints, and the metacarpal bone of the thumb moves freely on a hinge joint. As stability is the leading character in the lower extremity, the knee moves in one plane only, the fibula has no motion upon the tibia, the joints of the tarsus do no more than yield sufficiently to break the force with which the frame alights upon the ground, and neither of the metacarpal bones move on their carpal joints.

It would appear fanciful to enlarge upon the points of correspondence between the head and trunk. As the vertebral canal contains the spinal chord, the cranial cavity contains the cerebrum and cerebellum; as the main parts of the respiratory organs are contained in the upper cavity of the trunk, and the digestive viscera are supported by the lower, the nostrils are the cavities attached to the fore and upper part of the cranium, and the fauces are attached to the lower part. If the chest supports the organs of prehension, the pelvis those of pursuit, the orbits, the nostrils, the cavities of the temporal bone have points in common with the former, and the fauces, which contain the tongue, have a trivial analogy with the latter.

If we look to the physical strength of the skeleton, we may begin by enumerating the globular form of the skull, and the security it derives from the sphenoïd and temporal bones; but to pursue this theme would lead me to repeat remarks which have already been made, or would anticipate what belongs to the next head. Let me rather observe, that we are not to seek for indefinite strength and powers of resistance in the frame, but to admire the degree of security given to such frail materials, the equal strength of the whole, and the exact proportion of the means of defence in each part to the risks to which it is exposed.

When we look at the skeleton as designed for beings distinguished by the erect posture and erect progression, we notice the head so placed as to be poised upon the vertebral column,—the lower cervical vertebræ deficient in those processes, which in quadrupeds give attachment to a ligamentum nuchæ adequate to support a pendent head,—the vertebral column becoming broader towards its base,—the spinal column resting upon an elastic hoop disposed in a plane nearly vertical—the centre of gravity falling in the right line which joins the two acetabula, so that the body may be swayed with security in any direction upon the ossa femoris,—the margin of either acetabulum thickest and deepest at its upper and back part,—and the foot forming an elastic arch upon which the frame securely rests.

The structure of the muscular substance employed in supporting and moving the frame has been already described. The muscles of the trunk and limbs have at least two attachments to bone, one of which is called their origin, the other their insertion. The former term is usually applied to that attachment which is nearest the centre of the body, or which under ordinary circumstances is the fixed point during the action of the muscle. By its origin and insertion a muscle adheres to two separate bones, which either are articulated together or have a third bone or even several interposed. In the latter case a single muscle is adapted to bend or extend several joints.

Muscular fibres in some instances adhere directly to the periosteum of a bone, in others are united to it by an intermediate chord of the same texture with a ligament, in this case termed a tendon or sinew. Every muscle of the class under consideration has a tendon at one extremity; and commonly at both, tendinous fibres are wrought up in its texture.

Some have illustrated the connexion between a muscle and a tendon in the following manner. Each fasciculus of a muscle, as has been already remarked, has its sheath of membrane; we have but to suppose, this sheath prolonged beyond the termination of the fibre, as a compact thread, and we have a tendon produced. On this supposition, the definite proportion between the strength of a muscle and its tendon would be essentially provided for by an union of threads in the texture of the latter equal in number and coarseness to the fasciculi of the muscle.

The various uses, which tendons serve, require an elaborate explanation.

The strength of a muscular fibre does not alter with its length. A long and a short chord of the same texture and thickness require an equal force to tear them asunder. The strength of a chord is that of its weakest point. It must be the same with a muscular fibre. We may suppose the contraction of a muscular fibre efficient at any degree below the maximum force of its weakest part; but if the resistance opposed to it exceed the force of the latter, it is obvious that the extension or rupture of the fibre at that part will neutralize the force of the rest. All that the remaining parts of a muscular fibre can do, is by exerting an equal force with the weakest to prevent the waste of any of its effect.

But the extent, to which a muscle can shorten, depends upon the length of its fibres. It is ascertained that a muscular fibre is capable of contracting to a limited degree only: when a limb has been broken, and through ill management has become materially shortened, its muscles are for a time rendered useless, although they subsequently accommodate themselves to the altered length of the limb. Let us assume then that a muscular fibre in action can only diminish its length by one-third: it follows, that a muscular fibre of three inches in length would in its utmost contraction bring its points of attachment an inch nearer than before, whereas a muscular fibre a foot in length would be capable of reducing the distance between its points of attachment four inches.

Now let us suppose, that the distance between the origin and insertion of a muscle be one foot, but that the necessities of the frame never require that its attachments should be brought nearer than eleven inches. It is obvious that in such a case three-fourths of the muscular fibre would be useless, and that their place might as well be supplied by an inextensible substance. In the wise economy of Nature this circumstance has not been overlooked: in cases similar to that supposed, as in the instance of several of the muscles which move the wrist, tendon is used in the place of an unnecessary length of muscular fibre, and a considerable expense of muscular power is saved.

In the preceding instance a provision is made for symmetry. The graceful outline of the leg and ancle is produced in a similar manner; the volume of the limb being diminished at the lower part by the substitution of tendon for muscular substance. Upon other occasions the same object is attained by a different contrivance. The leg, to continue the last illustration, would certainly lose its symmetry, if it had a calf on the fore part; or in other words if the muscles, which bend the ancle joint, formed a short thick mass of flesh below the knee, with tendons tapering to the instep. Instead of this arrangement, the short fibres, which belong to the extensors of the toes, rise from the whole length of the tibia and fibula; and each muscle has a long tendon beginning at its upper part, to which its fibres are inserted in succession, so as to produce a resemblance to the feathered part and stem of a quill: muscles of this appearance are hence termed pennated muscles. Sometimes it happens that the symmetry of a limb is best consulted by interposing the muscular substance between two tendons: the rectus femoris thus has a long tendinous origin as well as a tendinous insertion. In this and similar cases a second advantage is gained: a tendinous attachment occupies a much smaller surface of bone than a muscular attachment.

The attachment of a muscle to bone is fleshy instead of tendinous, either when symmetry is gained by this disposition of parts, or when it is requisite that different fasciculi of the same muscle should draw in different directions.

In the rectus femoris, the semimembranosus, and other muscles, in which a mass of muscular substance is interposed between two tendons, each tendon forms near its attachment a strong thick chord, but spreads out, and terminates as a membrane, towards the belly of the muscle. It is to be remarked that in these instances the two membranous expansions are formed upon opposite sides of the muscle. The end attained by this arrangement is very apparent; it provides for the equal length, and consequently for the equable action of all the fibres.

In the majority of instances the direction of muscles is parallel, or at least not vertical, to the axis of the bone which they move; so that their action is for the most part oblique. It is obvious that this application of force is attended with a considerable loss of power:—an advantage however of another kind is gained by it. A muscle thus disposed is capable of moving the point of its insertion through a large space, while the extent, to which it *shortens*, is very trifling. The action of the supinator radii longus may serve to illustrate this position: but the instance of the intercostals is more obvious and more commonly selected.

The muscles of the trunk and limbs are distributed in a double series, the one as antagonists to the other: nevertheless those, which on one occasion are directly opposed to each other, on another may act in concert. Thus the pectoralis major is employed in carrying the humerus forwards, the latissimus dorsi, in carrying it backwards: but both may concur in simply depressing it.

The problem solved in the direction and place assigned to different muscles is probably, in what manner should they be disposed, in order that they may individually combine in the greatest variety of actions, and that one type may serve for the frame of numerous families of animals with habits essentially different. It is a remark not without the profoundest interest, that in many instances parts serviceable in one animal are found to exist in others where they are evidently useless,—if indeed that provision be useless, which stamps the strongest evidence of an uniformity of design in the various families of animals, by leaving vestiges of organs in one race, which only find their physical importance and development in other beings.

The plantaris is a part of this description: it is inserted in man into the heel bone exclusively. But in simiæ this muscle is attached to the plantar fascia, so as to give tension to that membrane, with a view to the protection of the plantar vessels and nerves, when the prehensile foot of the animal grasps any hard substance.

As might be expected, various theorems in mechanics find an illustration in the common frame of the bones and muscles. In every movement of the body, a lever of one kind or another is set in motion.

A lever is supposed to be an inflexible line, which is moved upon a point termed its fulcrum, that is placed either at one extremity or intermediately, by a force applied at a different part, so as to overcome a resistance which operates upon a third point of the lever. Three sorts of levers are formed by varying the relative place of the fulcrum, the power, and the resistance. In the first, the fulcrum is intermediate, in the second the power, in the third the resistance.

The mechanical advantage of a lever is easily estimated; the power or the resistance has the advantage in proportion to its relative distance from the fulcrum, or in proportion as the length of the arm, on which the one operates, exceeds the length of the arm on which the other operates. An equilibrium is produced, when the force and resistance, and the distance of each from the fulcrum, are equal.

On the other hand, in proportion as power is sacrificed, velocity is gained. Whenever the resistance operates upon the longer arm, the weight lifted traverses in the same time a greater space, than the point at which the force is applied. Now rapidity appears to be a more important object to be attained in the movements of the animal frame, than mechanical force: accordingly in most instances the second kind of lever is employed, which essentially involves a greater distance between the resistance and the fulcrum, than between the power and the fulcrum. To such an extent is this principle carried, that in order to balance a weight of one pound in the hand, the biceps flexor cubiti, if it were possible to suppose it acting alone, must exert a force equal to ten pounds.

On many occasions velocity again is obtained by the numerous joints, which move in concert to one object. Thus when a straight blow is struck, the hand moves forward with greater velocity than is communicable by a single set of muscles; at one and the same instant the humerus is raised, and the fore-arm depressed; and the fist, projected by two forces, moves in the diagonal between both impulses.

The only instance, in which the third kind of lever is employed in the human frame, and velocity sacrificed to power, is to be found in the foot:—the tendo Achillis is attached to the long arm of that lever, which raises the weight of the body upon the ball of the great toe.

The strength of muscular fibre is unknown: but it is supposed that a muscle, the section of which would present a surface an inch square, might exert a force equal to five hundred pounds. It seems likely that there may be an original difference in the quality of muscles; and that some of greater volume are essentially weaker than others less in bulk but of more rigid fibre. Much, however, depends upon the energy, with which the will operates. During phrenzy, a slight and feeble frame is often found capable of going far beyond the most powerful efforts of the strongest man, when acting under less excitement.

The continued action of a voluntary muscle must metaphysically depend upon successive impulses of the will, repeated at infinitely short intervals; and a curious observation of Dr. Wollaston's makes it appear, that in a continued muscular effort, the renewal of the muscular contractions may be even appreciable by the senses[a].

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[a] Phil. Trans. vol. c. p. 5.

The body stands, when erect, on the same principle as a modelled image of similar weight: its position is secure, as long as a perpendicular drawn from its centre of gravity would fall within its base. The muscles support the frame erect, by keeping the joints rigid in any attitude, which may be assumed involving the preceding condition. The securest posture, that could be given to a model, would be the securest for the human body. What renders the attitude of standing practically so firm in a living person is the power we have of anticipating the side, on which it will be necessary to make resistance, and of increasing the length of the base, on which we rest, in the direction, in which violence is threatened.

If a person standing erect be killed instantaneously, he drops prone on the ground: the body falls forwards, because the greater part of its weight is naturally placed before that column, which, in the case supposed, suddenly gives way, at every point where there is a joint. The tendency of the body to fall forward seems provided against accidents of a less grave character, to which we are occasionally liable: we thus fall, when we lose our balance, against objects, which we see, and towards which our hands and arms are readily advanced to break our fall.

In the more violent kinds of locomotion, in vaulting, and running, the body is thrown forward by the re-action of the soil, that follows the sudden pressure made upon it by a simultaneous contraction of the extensor muscles of the ankle, knee, and hip.

The insecurity attending the preceding methods of progression is avoided in walking, in which the support of the body is alternately transferred from one leg to the other, and one foot is always planted on the ground.

When we purpose to step forward in walking, we begin by inclining the body to one side, so that it rests upon one leg. The opposite limb is then advanced, the knee being at first slightly bent in order to detach the foot from the ground. The hip-joint of the first limb is finally extended, by which means the trunk is propelled forward, so as to be received the next instant upon the limb which was advanced. Each step may thus be resolved into three elementary movements.

The different gestures of the body, like the tones of the voice, betray the presence of strong emotion. In anger the step is hurried, as the accents are; the hand is unsteady, when the mind is agitated, is spread abroad in wonder, is clenched in agony.

Voluntary muscles are observed to take a bias towards those actions, which they have several times repeated. The hard-working mechanic, when he divests himself of the dress and implements of his trade, betrays by the carriage of his limbs the occupation, to which his working day labours are devoted.

Individual character is formed by the adoption of peculiar habits of thought and feeling: now each mood of thought and feeling has its corresponding sign in some change of feature: but changes of feature or changes in the expression of the countenance are produced by muscular action; and the muscles of the face like those of the trunk and limbs unconsciously take a tone from the actions, in which they are frequently employed:—thus the prevailing character of the mind becomes faithfully pourtrayed in the lineaments, which the countenance wears, even when the mind and the features are in perfect repose.

CHAPTER XV.

OF GENERATION.

GENERATION consists in the growth of a seed, or germ, or embryo upon a living surface, from which it separates, when it has become capable of independent existence. In following the ascending scale of organization, either in plants or animals, the genital system is found to resolve itself into two parts, in one of which the germ grows, while in the other a substance is secreted, the contact of which appears to fecundate the germ. When these organs are met with in the same individual, the plant or animal is termed an hermaphrodite; when in different individuals, the distinction of sexes into male and female arises.

In human beings, the female organs consist of the ovaries, the uterus, the vagina: the male organs consist of the testes, the prostate gland, the glands of Cowper, the penis.

The ovaries, which form the essential part of the female organs, are two flattened oval capsules, that are lodged in the fold of peritoneum, which forms the broad ligaments of the uterus. When cut into, they are found to consist of a loose succulent texture, in which there are several small cysts, termed corpora Graaffiana, containing a serous liquid; their number is from fifteen to twenty; they vary in size, the largest being about four lines in diameter. At an early age the surface of the ovaries is smooth; as life advances, it becomes marked with numerous scars or cicatrices. At the same time one or more of the cysts are commonly found filled with a yellowish material of the consistence of curd; this appearance constitutes a corpus luteum. The ovaries are supplied with blood by the spermatic arteries, with nerves from the spermatic plexuses: on their removal the sexual passion is entirely destroyed.

The uterus is a hollow fleshy organ placed between the bladder and rectum. Its texture is fibrous, but much firmer than muscular substance. The broader portion or body of the uterus contains a triangular cavity, from two corners of which a tube termed the Fallopian tube leads towards the ovaries. The Fallopian tubes are about five inches in length; they become tortuous and enlarged towards their ovarian extremity, which is open, and fringed with irregular filaments or fimbriæ, that are capable of attaching themselves to the ovaries.

The third corner of the cavity of the uterus leads by a long channel called the cervix uteri into the cavity of the vagina. The aperture of the uterus is called the os tincæ.

The vagina is a mucous canal surrounded by a thick vascular membrane. At the orifice are the labia and clitoris; and in virgins a crescentic fold of membrane, termed the hymen, is found, leaving a narrow aperture.

The testes, which form the organs essential to the genital system in the male sex, are glandular bodies. Either testis is suspended in the scrotum by a part called the spermatic chord, which consists of the spermatic artery and veins, of the spermatic plexuses of nerves and absorbents, and of the vas deferens, or excretory duct of the testis. The testis is covered with a serous membrane called the tunica vaginalis. When the reflected layer of this membrane is divided, the testis is found to consist of a flattened oval substance; to the upper, outer and back part of which a narrow flat slip of flesh adheres called the epididymis.

The vas deferens becomes extremely tortuous, as it approaches the testis. When the duct has been filled with quicksilver injected in a retrograde direction, or towards the body of the gland, we find that the epididymis is but a continuation of the same canal, now reduced to a much less diameter,—of enormous length, though coiled upon itself into so small a compass. The upper end of the epididymis again leads by six or seven convoluted tubes, called vasa efferentia, to the upper part of the testis, the texture of which is firmer and denser than the rest: this part is termed the corpus Highmorianum, or rete testis. It consists of a network of tubes continuous on the one hand with the vasa efferentia, on the other with the substance of the testis, which is itself wholly made up of fine convoluted tubes. The connexion between the veins and arteries of the testis and this tubular structure is unknown.

The vas deferens is of great strength and relative thickness. Upon dividing it near the testis in animals recently killed, a fluid is obtained, which consists chemically of water, mucus, soda, and phosphate of lime, and contains numerous minute animalcules, which have a rounded head, and a tail. These animalcules are not found in the seminal fluid of mules[a].

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[a] Magendie. Elémens de Physiologie, vol. ii. p. 518.

The division of the spermatic chord on both sides, or the removal of both the testes, destroys the sexual passion, and produces impotence.

The vas deferens reaches the lower opening of the pelvis by a circuitous route: having passed through the spermatic passage, it descends by the side of the bladder to the under part of its cervix, where it is joined by an oblong body called the vesicula seminalis: the latter part consists of a long blind tube, folded upon itself, the open extremity of which enters the vas deferens at an acute angle. The common duct after this junction is about half an inch in length: it perforates the prostate gland between the third lobe and the lateral lobes, to open upon the under part of the urethra by an aperture at the side of the caput gallinaginis.

In the body of a stout muscular subject, which I accidentally examined, I met with no vas deferens in either spermatic chord: I found, however, that the structure of the testis was natural, and that the vas deferens was formed in the usual manner, but instead of ascending in the chord as usual, it was reflected downwards and opened into the rete testis. In the place of the vesiculæ seminales, on one side there was a narrow slip of dense fleshy substance, which was not tubular; on the other, every vestige of this organ was wanting.

The prostate gland is of the size of a small chesnut, and of great toughness; its numerous ducts open in the furrow at the side of the caput gallinaginis, and pour out, when the gland is squeezed, an opake whitish liquid.

The glands of Cowper seem likewise to belong to the generative system; they are of the size of pease, one being placed on each side of the membranous portion of the urethra, below which they are united by an isthmus: the duct of each, about three inches in length, opens by perforating the mucous membrane lining the spongy body of the penis.

The secretions of these parts find therefore a ready passage into the bulb of the urethra, from whence they are expelled by the action of the ejaculator seminis.

In perennial plants the organs of generation are annually shed and reproduced. In animals the sexual organs are periodically fitted for the function of generation either by their actual enlargement, or by a determination of blood to them at particular seasons. In human beings the sexual organs are competent to their function during the greater part of life, from the age of puberty to forty-five or fifty in females, to sixty-five or seventy in men.

The period of puberty is different in the two sexes, in the inhabitants of different climates, in persons of different temperaments and habits of life.

Women reach the period of puberty one or two years before men; the inhabitants of southern, before those of northern climates. In the hottest regions of Africa, Asia, and America, girls arrive at puberty at ten, even at nine years of age; In France not till thirteen, fourteen, or fifteen; whilst in Sweden, Russia, and Denmark, this period is not attained till from two to three years later. Habits of activity and bodily exertion retard the arrival of puberty.

Before this period the generative organs are disproportionately slow in their growth, and the collateral differences, which subsequently characterize either sex, have not made their appearance. In a boy and girl there is no great difference in external form, in the tone of the voice, in the appearance of the integuments.

At the time of puberty, in the male, the larynx enlarges, the quality of the voice is changed, the beard grows, the chest and shoulders enlarge, the generative organs are developed, hair grows upon the pubes, and the secretion of the seminal fluid begins.

The female at the age of puberty deviates less from the type of childhood; but the breasts enlarge, the pelvis enlarges, the uterine organs are developed, and a peculiar periodical secretion commences from the inner surface of the uterus, which continues, subject to certain intermissions, as long as the organ is capable of impregnation, on an average about thirty years.

This secretion is termed the menstrual discharge or catamenia: it returns every lunar month, and consists of a fluid resembling arterial blood, except that it does not coagulate: the secretion amounts to six or eight ounces on an average, and lasts from three to four days. But in some instances the period returns regularly every third week; and in other instances, in which the common period is usually observed, it occasionally happens, that menstruation is put off till the fifth week without any inconvenience attending: in some persons it lasts a shorter period than that above stated, and is scarcely sanguineous, in others it is more profuse and lasts at each recurrence a week.

In some instances menstruation takes place at puberty without any previous or attendant indisposition, but generally its first appearance is preceded by uneasy feelings, by pain about the back and pelvis, accompanied often by disorder of the stomach and bowels, and various hysterical symptoms. These affections gradually abate, but at the end of a month return with more severity, being attended with colic pains, a frequent pulse, occasionally with heat of skin and a desire to vomit. There now takes place from the vagina a discharge of a serous fluid slightly red, but it does not in general become perfectly sanguineous for several periods: when the discharge flows, the preceding symptoms abate, but frequently a considerable degree of weakness remains, and the skin of the eyelids appears discoloured. In a short time menstruation is performed often without any other inconvenience than a slight pain in the back, though sometimes a woman may suffer from many of the former symptoms every time she is unwell; and all women at the menstrual period are more liable than at other times to spasmodic and hysterical complaints.

This secretion is naturally wanting during uterogestation, and some time subsequently.

It is supposed that the uterus is peculiarly fitted for impregnation immediately after the period has ceased. Yet women may have children antecedently to the occurrence of menstruation. Sir E. Home mentions the case of a young woman, who was married before she was seventeen, and having never menstruated, became pregnant; four months after her delivery she became pregnant a second time; and four months after the second delivery, she was a third time pregnant, but miscarried. After this she menstruated for the first time, and continued to do so for several periods, and again became pregnant[b].

As long as the uterus is capable of becoming impregnated, it appears that ova are continually formed in the ovaria. The corpora lutea appear to be the beds in which ova grow: the yellowish granular substance, of which a corpus luteum consists, is found to have a central cavity, in which the germ is detected, partly adherent, partly surrounded with blood. This important discovery was made by Sir Everard Home and Mr. Bauer. In the body of a young woman twenty years of age, with a perfect hymen, a corpus luteum was examined, that was seen in one of the ovaria; the ovum which it contained was an oval substance $\frac{15}{200}$ of an inch in length, less than $\frac{5}{200}$ in breadth, something contracted in the centre, transparent, imperfectly covered by a membrane, by which it adhered to the corpus luteum. The Fallopian tube on that side was fuller than on the opposite. The fimbriæ were spread out and unusually vascular: no sexual intercourse had taken place[c]. Mr. Bauer has since repeatedly verified the correctness of this observation in animals; and has additionally ascertained, that the corpora lutea, when the ova are fit for becoming fecundated, burst and expell their contents; and subsequently shrink and disappear.

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[b] Phil. Trans. vol. cvii. p. 258.

These interesting observations have the advantage of bringing under one theory all the instances of generation with separate organs, by proving that in the case of mammalia, as in other animals and in plants, an ovum is prepared by the female, previously to a fruitful connexion.

There is reason to believe that the collateral changes, which take place in the human body at the term of puberty, are immediately dependent upon the state of the genital system.

The effect of castration upon animals is well known:

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[c] Phil. Trans. vol. cviii. p. 61.

in boys, it prevents the enlargement of the larynx and the growth of the beard, and the whole frame presents an inconsistent and effeminate character ever afterwards.

In a similar manner where parts of the genital system are naturally deficient, the body never acquires the true character of either sex. A marine aged twenty-three was admitted in the year 1779 into the Royal Naval Hospital at Plymouth: he had been there only a few days, when a suspicion arose of the individual being a female. He had no beard: his breasts were fully as large as those of a woman at that age: he was inclined to be corpulent: his skin was uncommonly soft: the hands fat and short: the thighs and legs like those of a woman. The penis was found to be unusually small, the testes not larger than in the fœtal state.

A female lived to the age of twenty-nine years, who was of a fair florid complexion, in stature not more than four feet six inches; her breadth across the chest was fourteen inches; across the pelvis but nine: her breasts and nipples had not enlarged. She had never menstruated. There was no appearance of hair on the pubes, nor was there any indication of puberty in body or mind at twenty-nine years of age. It was found on examining the body after her death, that the os tincæ and uterus had their usual form, but had never increased beyond their size in the infant state. The passage into the uterus through the cervix was of the common shape, and the Fallopian tubes were pervious to the fimbriæ. The coats of the uterus were membranous. The ovaria were so indistinct as rather to show the rudiments, which ought to have formed them, than any part of the natural structure.

Mr. Hunter has described the nature of a peculiar monstrosity, which occurs in black cattle, and which throws additional light upon the present subject.

When twin calves are born, they may be both perfect bull or perfect cow calves: when one is a bull calf, the other a cow calf, the latter in general, when grown up, exhibits no sexual propensities, and has a frame resembling the common ox, with which animal it is generally yoked and employed. This animal is termed a free-martin. Upon an examination of three of these animals, Mr. Hunter found in them different malformations of the genital organs: each of them had some rudiment of the female organs, but at the same time something deficient, either in the connexion of the uterus with the vagina, or in the development of the ovaria; and in each some small part of the male generative system was detected. In this instance therefore, as in the preceding, the general character of the animal seemed to follow the type of the genital organs.

The free-martin is perhaps the nearest approach in the higher animals to the state of hermaphrodism, the existence of which in human beings is a groundless fiction. Those appearances, which are occasionally exposed to the vulgar, as specimens of such an occurrence, are cases in which, if females, there is an habitual prolapsus of the uterus with a long and narrow cervix, or an enlarged clitoris; or in which the front of the bladder and the lower part of the abdominal parietes are deficient, so that the everted mucous surface of the posterior half of the bladder presents the appearance of a glans penis above the female sexual organs;—in males, the want of a perforation in the penis, with a deficient septum scroti, and the urethra opening in the perineum, may give rise to a similar imposition.

The state of the uterine organs when fitted for impregnation may be collected from the following observations made by Mr. Cruikshank. A female rabbit, when at heat, was pithed, and the uterine system minutely examined. The external and internal parts of generation were found black with an unusual quantity of blood: the Fallopian tubes were twisted like writhing worms, and exhibited a very vivid peristaltic motion: the fimbriæ embraced the ovaria, like fingers laying hold of an object, so closely and so firmly as to require some force and even slight laceration to disengage them: round black spots somewhat less than mustard seeds appeared below the membrane of the ovarium. Upon injecting the vessels of the pelvis with size and vermilion, the uterine organs became of a bright red.

We have next to inquire what conditions are requisite to fertilize the ovum, or to produce conception. Upon this subject our knowledge is extremely imperfect; but proceeding by the inductive method, physiologists have ascertained, that the exclusion of one element in the structure of the uterine system, essentially prevents impregnation following sexual connexion. If the canal leading from the orifice of the vagina to the ovaries be interrupted, conception never takes place. If the obliteration take place at the vagina, the sexual appetite remains unaffected; if, as has been already mentioned, the Fallopian tubes be the parts divided, desire appears to be lost, as well as the capacity of being impregnated.

Let me state the facts in detail on which these conclusions rest.

Dr. Blundell found that the obliteration of the uterine canal in rabbits, by division of the vagina, prevents conception. In animals thus mutilated, which admitted the male, the uterus enlarged to a considerable size, and was found to contain a fluid of an albuminous nature[d].

The following case occurred in my own practice. A married woman 33 years of age had borne several children, but after her last labour, violent inflammation followed, which produced a complete obliteration of the cavity of the vagina by adhesion. Conception did not take place subsequently, but she suffered periodically under a complication of head-ache, epilepsy, hemiplegia, and vomiting of blood. Her sufferings having lasted five years, and continuing to increase, she applied to me for advice. The uterus, when examined by the rectum, was evidently not enlarged, and contained no fluid. Nevertheless, in the hope of restoring the functions of the part, I determined to try to make an artificial passage to the womb, by perforating the centre of the firm flat chord, which represented the vagina. Upon exposing the os tincæ, however, it appeared that the cavity of the uterus had likewise become obliterated in this case. To make sure, I divided obliquely the extremity of the cervix uteri, but could find no route leading into the cavity of the uterus, on pressing the end of a probe against the cut surface. It is now 3 years since the artificial vagina was made; it has shown no tendency to close; conception has not taken place, but the symptoms at each period are by no means so severe as formerly.

Barrenness in married women occasionally depends upon an obstruction of the os tincæ by viscid mucus, the removal of which through the introduction of a bougie has been shortly after followed by conception.

Dr. Haighton divided the Fallopian tubes on each side in several female rabbits, and found that the animals invariably lost the sexual appetite[e]. Upon dividing the Fallopian tube on one side only, he found the same result generally ensue. In a few cases, however, the animals thus mutilated admitted the male, and became impregnated; but the horn of the uterus on the side, on which the Fallopian tube had been divided, never contained ova.

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[d] Medico-Chir. Trans. vol. x. p. 50.

When we refer to analogy for some elucidation of the cause, why an obstruction of the uterine canal prevents conception, we seem to discover it in the fact, that in various cold-blooded animals, the seminal fluid is brought into contact with the ova either at the time of their expulsion or afterwards; and we are led to conjecture, that in warm-blooded animals likewise the seminal fluid must be directly applied to the germ, in order that impregnation may take place.

If we are satisfied that this conjecture is well grounded, we may next inquire, whether the contact of the seminal fluid and ovum takes place in the uterus, in the Fallopian tube, or in the ovarium. The only fact, of which we are in possession, that seems to bear upon the question at issue, is that the ovum although generally developed in the uterus, sometimes is brought to maturity in the Fallopian tube, and sometimes in the ovarium itself: it is remarkable that in the two latter cases, the uterus enlarges, and its inner surface becomes covered with a layer of flocculent lymph, in the same manner as in cases of ordinary conception: but curious as these occurrences are, I am afraid that they leave the point, I have adduced them to illustrate, nearly in its original obscurity.

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[e] Phil. Trans. vol. lxxxv. p. 108.

But in instances where the generative system appears physically perfect on either side, nothing is more uncertain than the occurrence of conception in women; we are totally ignorant of the causes, which prevent it at one time, and facilitate it at another; even the signs, which announce the presence of this state, are liable to prove fallacious, and at an early period, dissection alone or the accident of an abortion happening, can show, by producing the impregnated ovum, that it has existed. Nevertheless in married women who have been previously healthy, the cessation of the catamenia, and the constant recurrence of sickness in the morning, are symptoms which declare with tolerable certainty, after a few weeks have elapsed, that conception has taken place: afterwards, the enlargement of the abdomen and of the mammæ, the emaciation of other parts, not attended with loss of health but with an increased appetite, and latterly the sensations produced by the movements of the fœtus, conjointly establish to a moral certainty, the nature of the change which is proceeding.

The earliest appearance of the human ovum upon record is that described by Sir Everard Home.

A young woman died under circumstances, which made it evident that eight days before she had cohabited with a person, whom she had not subsequently seen.

Upon examining the uterine system, the cavity of the womb was found lined with an exsudation of coagulable lymph, and a small body was seen, which lay in the lymph near the cervix. Mr. Bauer found that this small body consisted of a membrane of great relative thickness, forming a bag or pouch of an irregular oval shape, not quite $\frac{19}{200}$ parts of an inch in length, and in its middle about $\frac{9}{200}$ parts of an inch broad.

When laid on glass, the membrane admitted easily of being opened with a camel's hair pencil, at a point, where a natural fissure seemed to exist. It was found to contain another smaller bag, somewhat less than $\frac{18}{200}$ parts of an inch in length and not quite $\frac{5}{200}$ broad: the bag was contracted in the middle: it consisted of a thin but firm membrane, which seemed to be filled with some thick slimy substance, it contained two round corpuscles, apparently more opake and of a yellowish tint: these distended the membrane over them, so as to be distinctly seen.

Towards the close of the third week the ovum appears a flattened egg-shaped cyst, with a flocculent external surface, which is termed the chorion; a smoother membrane lines this, termed the amnios, in which is a fluid called the liquor amnii. The embryo floats in the liquor amnii, and is attached by the umbilical chord or navel-string to the thickest part of the chorion, which is termed the placenta; the amnios is reflected from the placenta along the umbilical chord to the embryo.

The embryo about the third week resembles a bee: the head has the greatest bulk; from the curved oval body the extremities project like little shoots; between the two lower extremities the body is elongated into a sort of tail, termed the coccygeal protuberance. The neck, at first large and short, is scarcely recognizable during the first two months. At the end of the second month the different divisions of the limbs are distinct, and the fingers and toes shoot out. The arms and fore-arms are developed before the legs; as the latter grow, the coccygeal protuberance diminishes; it has disappeared by the end of the third month: it is not till the fifth month that the lower extremities acquire their superiority in size.

The embryo grows fastest the first month after conception; its growth is retarded during the second month, accelerated during the third, and retarded during the fourth. About this time all its organs having made their appearance, it is termed a fœtus; the growth of the fœtus is then accelerated to the end of the eighth month, but afterwards proceeds slowly.

From measurements by Wrisberg, Burns, and others, it appears that an embryo of six weeks weighs about thirty-seven grains, at ten weeks ʒiij, at twelve weeks ℥ij, at the sixth month ℔j, at the eighth between four and five; at birth the average weight is 7℔ avoirdupois, and varies from 4℔ to 11½. The average height is twenty inches. Twins are individually smaller: males are larger than females; the head is longer and flatter, and the chest more developed in the male.

In the first and second months the embryo appears bent, in the third a little straightened; afterwards it becomes convoluted into an oval. The vertex of the head makes one end of the oval, the nates the other: one side or edge of the oval is formed by the occiput, the back part of the neck, and the incurvated trunk, the other is made of the forehead and folded limbs: the hips and knees are bent and the legs crossed; the upper extremities are folded in the vacant space between the forehead and knees. But the position of the extremities varies in different cases, and seems often shifted in the living body. With regard to the mother the most common situation of the child is with its head downwards, and its nates at the upper part of the uterus: once perhaps in twenty or thirty cases it is the reverse.

The genital organs are distinct in the third month:

the clitoris is large and prominent, so that a mistake as to the sex is readily made at this period. Of the organs of the senses, the eyes are first observed; they are proportionately larger as the embryo is younger. Soemmerring thinks that the eyelids are open before the tenth week: about the seventh or eighth week pores are seen in the situation of the external ears, then the helix and antihelix, the tragus and antitragus, are developed. The mouth is open during the first month, there being as yet no lips. The cutis is at first thin and gelatinous, but is covered by a cuticle in the earliest stage: the surface of the body is red and vascular at an early period, an appearance common to all the families of mankind: the dark shade of the Caffre and Malay comes in a few days after birth. The surface of the fœtus is covered with a firm sebaceous and white substance termed vernix caseosa: this covering, which renders the whole body greasy, cannot be washed off with plain water. It is insoluble in alcohol, oils, or pure water, but some alkalies dissolve a part of it and form a kind of soap: it is found on the surface of the child alone. A soft woolly covering is seen particularly about the sides of the face the back and shoulders and hips in young embryos, which disappears in the mature fœtus. Proper fat is not formed under the skin before the fourth month: its place is occupied by a jelly-like substance: afterwards a pretty thick layer of fat is formed over the whole body. Muscles are not distinguishable in the first three months, after which fibres are slowly formed: in an embryo of 3½ months Wrisberg observed muscular fibre and tendon. It is observed by Soemmerring that the tendons of the recti abdominis are proportionately broader and stronger than in the adult. The pyramidales also are considerably larger. There is a round opening in the linea alba for the passage of the umbilical vessels. The muscles of the internal ear are nearly completed at the time of birth. The intercostals and diaphragm are considerably developed at the same period, and the muscles of the upper more than those of the lower extremity. The total length of the cerebrum at three months is 1 inch 3 lines, breadth 1 inch 1 line: at birth its length is from 3 inches 8 lines, to 4 inches 6 lines. The absolute increase of the cerebrum and cerebellum is greater during the six months preceding birth, than during the seven succeeding years. The convolutions of the cerebrum begin to be formed the third month; they are marked by mere superficial depressions; they appear first in the middle and posterior lobes. They are distinct by the seventh month: the laminæ of the cerebellum appear somewhat earlier. The globules, of which the fœtal brain is composed, are smaller than those of the adult. At three months the whole enkephalon is of a pearly colour with no distinction of white and brown; at this time the mass is nearly semifluid, and even at five months there is no distinction. The substance of the spinal chord in the fœtus is much firmer than that of the brain.

About the seventh month the edges of the pupil are united by a fine vascular membrane, termed the membrana pupillaris, which is imperfectly seen before and after this period. At the time of birth there are no valvulæ conniventes in any part of the small intestines, except the duodenum. The testes of the fœtus are situated immediately below the kidneys; a flat chord termed the gubernaculum testis extends from each to the spermatic passage. About the time of birth the testis descends into the scrotum pushing before it a sac of peritoneum: sometimes a portion of omentum or intestine descends along with the testis constituting a congenital hernia: commonly however, nothing intervenes between the surfaces of the peritoneal canal which leads into the scrotum, and they cohere; by this means all trace is lost of the original continuity between the peritoneal cavity and that of the tunica vaginalis. In the fœtus a conical tube, called the urachus, extends from the fundus of the bladder to the umbilicus. In this stage of existence are developed certain glandular bodies, the use of which is unknown, but which continue large and vascular till towards puberty, and afterwards shrink and waste. The thymus gland is one of these; it consists of several masses of a yellowish parenchyma, that are united by cellular membrane only, and are disposed as two large lobes in the anterior mediastinum before the great vessels and the base of the heart: each subdivision of the thymus gland has a cavity, which contains an opake fluid of a dirty white colour. The renal capsules are two little crescentic bodies, of a granular texture, and very vascular, that lie before the upper part of the kidneys. These likewise have a cavity containing a turbid serum. They do not waste so early as the thymus. Perhaps with these parts the thyreoïd gland should be associated, the isthmus of which crosses the second ring of the trachea, the lateral lobes extending along the side of the cricoïd and thyreoïd cartilages. It is very vascular and laid out in minute cells. In this enumeration of the organs of the fœtus I have purposely omitted noticing the state of the skeleton, which will be described in the following chapter.

The fœtus floating in a liquid has no use for its lungs: its blood is purified in the placenta, a part remote from its body, to and from which the blood is transmitted through vessels contained in the umbilical chord.

The blood is distributed through the body of the fœtus in the following manner. A vein, termed the umbilical vein, enters at the navel, runs in the unattached edge of the broad ligament to the notch of the liver, pursues its course along the median fissure of the liver, gives off at the transverse fissure a large branch to join the vena portæ, and afterwards proceeds, under the name of ductus venosus, to open into the vena cava, in which the blood brought from the placenta becomes blended with that returned from the aortic circulation. The mixed blood enters the right auricle, and great part is transmitted directly through a circular aperture in the septum auricularum, called the foramen ovale, into the left auricle; to promote this object, the Eustachian valve is so disposed, as to cause the axis of the vena cava ascendens to correspond with the axis of the foramen ovale. Either auricle contracting, the same quantity of blood is thrown into either ventricle: each ventricle propells its contents into the artery which issues from it: but the pulmonary artery at its point of bifurcation opens by a short capacious tube, termed the ductus arteriosus, into the under part of the arch of the aorta; and thus the blood, which escaped entering the left cavity of the heart, finally joins the rest in the aorta. The blood distributed in the ramifications of the aorta in part serves for nutrition, but a certain quantity is directly returned along its largest branches to the placenta to be purified: from each internal iliac, a great vessel termed an umbilical artery rises, which ascends by the side of the bladder before the peritoneum to meet its fellow at the umbilicus, where the two leave the body of the fœtus, and proceed to the placenta.

The umbilical chord, or navel-string, consists of three great vessels twisted, of the umbilical vein, and the two umbilical arteries, which are contained in a firm interstitial cellular mucilaginous substance. The thickness of the navel-string is variable; its length at the time of birth is on an average about two feet: but it varies from one foot to four. When very long, the umbilical chord is generally twisted round the child's neck: it has been known to have been so twisted four times and a half. This accident does not appear to affect labour, except in those cases, when the child is turned; and the child is then in considerable danger of strangulation.

The placenta, to which the chord is attached, generally near its middle, is a firm tough spongy mass, about an inch in thickness and a span in breadth: upon or near the inner surface of the placenta, the umbilical arteries and vein seem to ramify. On injecting the umbilical arteries, they are seen to anastomose immediately after entering the placenta: their branches are then distributed towards the circumference of the placenta, and divide and subdivide to the size of capillary vessels, which reuniting form the roots of the umbilical vein. The part of the placenta, which is occupied by the branches of the umbilical vessels, is termed the fœtal part: its inner surface is glossy, hard and compact.

But the injection of the umbilical vessels does not redden an outer layer, the maternal or uterine portion of the placenta: this is of a slighter and more delicate texture than the fœtal part: it adheres to the uterus, and is capable of being injected from the vessels of the uterus. The injection *never* passes from the uterine part into the fœtal, or from the fœtal into the uterine part of the placenta: but it is observed, that innumerable irregular cells are left between the maternal and fœtal portions, which are readily distended by any fluid thrown into the arteries and veins of the uterus:—we may presume, that in the living body these cells are constantly filled with arterial blood from the maternal system.

The mode in which the placenta operates in purifying the fœtal blood is unknown. The source from which the fœtus derives its nourishment, and the mode, in which the maternal and fœtal systems are connected together, are likewise involved in entire security. But M. Magendie mentions that the stomach of the fœtus has been found to contain mucus, which was opake and greyish towards the pylorus, as if converted into chyme; and a greenish substance, termed meconium, which may be the refuse of a kind of digestion, is found in the great intestines.

It is well known that physical and moral impressions upon the mother affect the health and life of the fœtus. M. Magendie further observed, that on introducing camphor into the veins of a pregnant bitch, in a quarter of an hour afterwards the blood of the fœtus had a distinct odour of that substance. The nervous system of the fœtus appears torpid: the symptoms, which active poisons produce upon the brain and spinal marrow in adult animals, do not follow their introduction into the serous cavities or cellular membrane of unborn animals.

But other parts of the ovum, and the membranes of the uterus, remain to be considered.

The amnios is a dense but transparent membrane, having a glossy internal surface; united to the chorion by an intervening gelatinous substance, to the navel-string directly.

The liquor amnii is a transparent fluid without any sensible degree of tenacity or ropiness; sometimes it is foul or muddy with a little of a yellowish cast.

Its proportion is greatest in the early months; in different cases its quantity varies considerably: in some instances at birth there is little more than a pint: in others it amounts to some quarts,—on an average to between two and three pints.

The following is the composition of the human liquor amnii.

Water	98·8
Albumen, Muriate of soda, Soda Phosphate of lime, Lime.	1·2
	100·0

When there is a considerable quantity of liquor amnii, the child takes the advantage of room, and the composition of its parts is less close and globular: in proportion as there is less space, the figure is more compacted and moulded to the shape of the uterus; the feet are even liable in such cases to be twisted to a degree of deformity.

The chorion is a complete bag of tender membrane inclosing the amnios, and continuous with the placenta: in the early months, it is uniformly thick and flocculent, so that the place of the placenta is less distinguishable; at the same period it is stronger than the amnios: but in the latter months it becomes thin and membranous, and has less strength than the amnios.

The vesicula alba is a small oval body containing a small quantity of a cream-like fluid, which is found at an early period of the ovum between the chorion and amnion. Its distance from the navel-string is various, sometimes half an inch, sometimes twice as much. From this bag a small duct is continued to the navel-string, which contains the same sort of white fluid as the sac itself; when the duct comes to the navel-string, it is as small as the finest hair, and with a magnifying-glass may be seen running along the whole length of the chord, adhering closely to the amnios.

The lymph thrown out in the uterus for the reception of the ovum is distributed in flocculent membranes termed deciduæ: one layer called the decidua vera may be traced lining the whole interior of the uterus: a second, the decidua reflexa, returns from the edge of the placenta to form an internal sac; this is somewhat of a yellower colour than the former: thus the ovum may be said to be contained between a part of the decidua vera and the decidua reflexa: but the distinction of two layers of decidua is not to be made out in every part of a single specimen.

The uterus grows with its enlarging contents, so as constantly to preserve about the same thickness; it is always more than sufficiently capacious, so as to be plastic, not tense.

About the fifth month it rises out of the pelvis, and rests against the front of the abdomen; as it enlarges, the distinction between the body and cervix is lost: the os tincæ is flattened and makes only a small rugous hole not readily discernible: it is closed by a tough glutinous matter which is fixed in the irregularities of the surface.

The fibres of the uterus assume something like a definite disposition as pregnancy advances: viewed from within they are seen to be disposed concentrically round the orifices of the Fallopian tubes. The cervix has not such regular or large fasciculi as the rest of the uterus: when the internal stratum is removed, the fibres of the next layer, which are firmer and tougher than the innermost, seem to have no regular order.

The ordinary period of uterogestation is nine calendar months: sometimes, however, but rarely, the child is born alive at the expiration of the seventh.

Labour is preceded for two or three days by a mucous discharge from the vagina, and by slight pains about the abdomen and loins. The external parts swell and become relaxed, and even the ligaments of the pelvis lose their tenseness.

The pains of labour commence with and consist in a powerful contraction of the uterus, accompanied with contraction of the abdominal muscles and diaphragm; they are repeated at intervals of half or a quarter of an hour. Impelled by this pressure the membranes project at and dilate the os tincæ; they burst; the liquor amnii escapes, and at the next pain the pressure of the uterus falls directly upon the fœtus. The head of the fœtus gradually descends urged on by succeeding spasms, the occiput foremost, the long axis of the head being disposed obliquely across the lesser basin of the pelvis. The occiput, as the external parts yield, glides off the inclined surface of the ischium, presenting at the orifice of the vulva, and bringing at the same time the long diameter of the shoulders to correspond with the greatest breadth of the pelvis. When the head is disengaged, the trunk readily follows. The umbilical chord is then tied, and divided.

After a short time fresh pains return, and the placenta and membranes are detached, and come away. Labour in the majority of healthy cases is completed in from four to six hours. The uterus then very slowly and insensibly contracts, so as to diminish the ample cavity, which has been rendered vacant. At the same time its volume is reduced by absorption. During the return of the womb to its former state, a discharge, at first tinged with blood, afterwards of a whitish colour, termed the lochia, ensues, which lasts for several days.

At the moment after birth the infant dilates its chest, and respiration commences; at the same time the foramen ovale and the ductus arteriosus contract, and close. A new mode of existence commences. The infant experiences sensations and wants, which adhere to it through life; it begins to receive impressions from the surrounding world, and tries instinctively to gratify its newly acquired appetites.

Yet for some time, the infant continues immediately dependent upon the maternal system for its nourishment.

The breasts form part of the generative system. The gland of the mamma, remarkable for the whiteness and firmness of its nodular texture, and for the mode in which it is mixed up with adipose substance, consists of several distinct lobes. From innumerable branches in each of these a duct is formed, which without communicating with those adjoining, opens in the sulci upon the surface of the nipple. The mamma has a close sympathy with the uterus, so that it usually enlarges and becomes tender for two or three days before each period. During the latter months of pregnancy the mamma enlarges, the areola surrounding the nipple taking a darker shade: towards the time of labour the breast secretes a serous fluid: the secretion has generally the same appearance for two or three days after labour, but at length takes the well-known character of milk. The secretion of milk naturally continues till the middle of the second year. The milk is observed to be more abundant, thicker, and less acid, when the food of the mother principally consists of animal substances: opposite qualities are noticed in milk produced upon a vegetable diet. No secretion indeed is more readily modified by the ingesta, than that under consideration: medicinal substances taken by the mother impart their properties to the milk; which is thus rendered purgative, as the consequence of a dose of rhubarb or of jalap.

The milk of women differs from that of cows in these particulars: it contains a much smaller quantity of curd, and rather more sugar of milk: its oil is so intimately combined with its curd that it does not yield butter. The quantity of curd increases in proportion to the time after delivery. Asses milk has a very strong resemblance to human milk[f].

The rudiments of mammæ originally exist in both sexes; and it is asserted, that there have been instances, in which the gland has been developed and has secreted milk in the male sex.

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[f] Thomson's Chemistry, vol. iv. p. 502.

CHAPTER XVI.

OF GROWTH.

I HAVE reserved for the concluding chapter some account of the growth of different parts, and of the mode, in which organized textures, when divided or broken, are repaired.

Let me begin by describing the growth of those parts, which, not vascular in themselves, are formed upon and adhere to living vascular surfaces.

The rudiment of each tooth is a vascular pulp of the shape of the body of the future tooth, the surface of which remote from the gum is continuous with the substance of the jaw and gives entrance to vessels and nerves: the rest of the pulp is unattached: a double membrane is reflected from the margin of the adherent surface, to form a cyst or capsule over the sides and upper part of the pulp. The outer layer of this membrane is soft, thick and vascular; the inner layer, which is in contact with the pulp, is thin and semitransparent; it shows no appearance of vascularity, when the outer layer is most successfully injected. In the cavity surrounding the pulp a transparent yellowish liquid is found.

The growth of the bony portion of the tooth commences, by the deposition of a layer of perfect bone upon the cutting edge or grinding surface of a tooth. This little cap of bone is therefore an exact mould of the surface, by which it was secreted: its adhesion is very slight to the surface of the pulp, which shrinks to give room for the exsudation of a second layer, that coheres inseparably with that first formed. When the pulp shrinks, it at the same time becomes elongated, but in such a manner, that the point where its vessels enter, remains fixed, and the crown of the tooth is raised towards the margin of the gum. In proportion as the pulp is elongated, the capsules of bone successively formed one within the other are of greater length, being cast upon a longer cylinder: in this way the whole bony portion of the tooth is produced, the pulp continually diminishing in thickness, but becoming elongated, till it has reached the exact dimension of the future cavity of the tooth. The pulp then ceases to secrete, and wastes to the condition of a vascular membrane, on which however the sensibility and vitality of the tooth, which it lines, depend.

The preceding circumstances may be verified by examining human teeth at different stages of their formation, and by sections of the teeth of an animal,—a growing pig for instance, with the food of which madder has been mixed, then discontinued, during alternate periods of two or three weeks. The bone of the tooth displays alternate layers of red and white, and the innermost layer is the longest.

During the elongation of the pulp, the capsule undergoes no change except in place; it rises with the crown of the tooth, to the neck of which it adheres. The enamel is not formed till some time after the bone, and invests that surface only of the tooth, which is contained within the capsule.

Some animals have teeth, the pulp of which never shrinks, but continually adds to the length of the tooth:

this is the case with the incisors of rodentia, and with the tusks of the elephant. The addition continually making to the roots of the incisors of rodentia is calculated to replace exactly the substance lost by attrition: these teeth continually rise in a curve towards each other, and are rendered more serviceable by the disproportionate thickness of enamel upon the convex surface, which thus always presents a hard and keen edge.

After the division of the fifth nerve in the cranial cavity of a rabbit, I removed the crown of one incisor tooth in the upper jaw, and compared the time it took to grow to the level of its fellow, with the result of a similar experiment upon a rabbit, in which the nerve had not been divided. The tooth grew rather faster in the former than in the latter instance.

The rudiments of the teeth in the embryo are at first contained in a shallow groove in either jaw, with thin partitions between each: they adhere more strictly to the gum than to the base of the socket. In an embryo of about the fourth month, twelve little sacs are observed in each jaw, being the rudiments of all the temporary teeth and of the anterior permanent grinders.

The shallow grooves, in which these pulps are first lodged, gradually rise and form alveolar processes: they arch over the pulps of the teeth, leaving, however, an opening towards the gum.

The rudiments of the earliest formed teeth of the second set are at first contained in the same sockets as the temporary teeth, but at the period of birth they are found in separate cells behind and without the cells or sockets of the corresponding temporary teeth. The cells of the second set again are not closed above, but have a narrow channel leading towards the gum, which contains a funnel-like process of the sac, that adheres to the neck of the corresponding temporary tooth.

In an embryo about the eighth month, the pulps of the permanent incisors and cuspidati are found. It is not till after birth that the rudiments of the remaining adult teeth make their appearance, in what order is not precisely known.

The twenty temporary or milk teeth begin to appear on an average about the sixth month. They generally cut the gum in the following succession: the middle incisors of the lower jaw, the middle incisors of the upper, the lateral incisors of the lower jaw, the lateral incisors of the upper,—at intervals of three, four, or five weeks: about the twelfth or fourteenth month, the anterior or small grinders of the under jaw appear, and frequently about the same time those of the upper: about the sixteenth or twentieth month, the cuspidati appear, first in the lower jaw; and between the twentieth and thirtieth month, the posterior or large grinders appear in the same order.

Before the teeth appear, the gums have a raised firm edge. To make way for the teeth, the upper vaulted part of the alveolar processes and the gums are absorbed. During this process indisposition frequently supervenes, which may be allayed by cutting down to the tooth at the part, where the gum appears slightly swollen: the division should be made anterior to the middle of the gum: if the incision were made upon the back part of the gum, it might open the socket of a tooth belonging to the second set, and spoil it.

The thirty-two permanent teeth begin to appear between the sixth and seventh year:—at this time the term of life of the milk teeth has expired; the gums and alveoli no longer adhere to them; they become loosened, and on dropping out, some degree of absorption is generally found to have taken place near the end of the fang. The shedding of the milk teeth does not essentially depend upon the forwardness of the second set: frequently the milk teeth fall out some time before the permanent teeth appear; or the permanent teeth rise, while the milk teeth continue firmly attached, and require extraction to give place to the second set.

The permanent teeth appear in the following order: first, the middle incisors of the lower jaw; soon after, the middle incisors of the upper; then the outer incisors of the lower jaw, and at the same time the permanent anterior grinders: then the lateral incisors of the upper jaw, after some interval. The anterior bicuspides appear about the ninth year, the posterior about the tenth or eleventh: the cuspidati and middle grinders about the twelfth or fourteenth, and finally the last grinders between the ages of sixteen and twenty-five.

Teeth, though not vascular, have some kind of life. A tooth taken from the head of a living person and immediately fixed in a living part, in the comb of a cock for instance, or in a socket from which another tooth has been drawn, adheres to the raw surface with which it is placed in contact, and becomes permanently attached to it. If the same experiment be tried with a tooth that has been some time removed from the living socket, it fails; the tooth is dead, and contracts no adhesion with a living surface.

The alveolar processes are formed with the teeth: in proportion as the teeth of the infant make their appearance, the branch of the lower jaw lengthens to give them room. When in old age, the second set of teeth drop out, the alveolar processes are absorbed; but the same active care is not then shown as during infancy in accommodating the neighbouring parts to this alteration; no ridge of thicker membrane forms upon the edge of the gum to take the place and office of teeth: and no adequate shortening occurs in the branches of the jaw, to allow the gums to meet in exact apposition, and to prevent the characteristic projection of the chin.

The unorganized integuments, the hair, the nails, the epidermis, are formed of the same chemical elements, which in animals assume the appearance of hoofs, horns, claws, and feathers; the element, of which they consist, exsudes in a soft state upon vascular surfaces, and quickly hardens by exposure. Of these substances hair and feathers grow upon pulps situated below the skin, the rest are secreted from the cutis.

The cuticle in human beings appears an uniform elastic membrane, the thickness of which is increased in proportion to the pressure made upon it. No definite structure seems fairly distinguishable in it: if on the one hand when forming warts, and on some other occasions, it splits into fibres vertical to the surface, in other instances the cuticle desquamates in layers parallel to the surface, and its texture seems laminated.

On examining parts in animals, with which the cuticle is continuous, horns for instance, and hoofs, two types of structure are apparent. Horn distinctly consists of fibres, of which the greater part are inclined at an acute angle to the surface, on which they grow: the fibres of the tip alone are vertical or nearly so. This structure is apparent on making sections of variegated horns, and upon peeling horns, that have been softened by maceration in diluted liquor ammoniæ, into strips. Hoof on the other hand has a porous tubular structure. The surface from which it is formed gives off innumerable long and slender villi, that descend in a vertical direction through the hoof towards its under surface, which they nearly reach. The delicate tubes, which render the substance of hoof porous, are the spaces occupied by these villi.

It may be remarked that hoof is a part sustaining a tolerably constant and equable pressure: horn on the other hand is only occasionally employed, and that in violent efforts. Now there are various instances in animals, in which the cuticle naturally has a thickness of several lines, and shows a definite structure. In some of these instances again, the pressure, which the cuticle sustains, is constant, in others occasional only:—it is singularly curious that in the former case cuticle is found to resemble hoof in structure, in the latter, horn. The cuticle of the whale is porous, and to the minutest points resembles the soft inferior and internal part of a horse's hoof. The cuticle of the ostrich's gizzard on the contrary is distinctly fibrous, even more so than the horn of the rhinoceros.

In the epidermis of the ostrich's gizzard the fibres are vertical to the surface; in a cow's horn, the fibres at the tip are vertical, at the sides oblique:—in each instance one principle is held in view; the fibres are so disposed as to be vertical to the pressure or attrition, to which they are likely to be exposed.

The structure of nail appears to be fibrous. The nails grow from a cutaneous surface at the back of the phalanges, which is less vascular than the adjacent skin: the upper part of this surface is seen distinctly defined through the semitransparent nail: the rest is hidden by a fold of skin, which secretes a layer of dense cuticle that adheres to and rises with the nail.

Each hair grows upon a pyramidal pulp placed beneath the skin; its central part is of less density than its crust: it is uncertain how far the pulp extends into this central part of a hair. In the disease termed plica polonica, the pulp evidently extends considerably beyond the level of the skin, so that the hair bleeds if divided: and it is difficult to explain the authenticated cases of sudden change of colour in hair, unless we suppose some mode of organization to be prolonged into its substance. If the whiskers of a cat be cut short, leaving only a third of an inch of each, they do not grow again, but are shed and replaced by others.

In a cat which lived after the division of the fifth nerve in the cranial cavity, the whiskers of the mutilated side became thin and crooked. Considerable branches of the fifth nerve are distributed to the whiskers of animals: in the seal each hair of the whisker receives a branch as large as a digital nerve in man.

The growth of bone is better understood than that of the soft and more vascular textures of the body. The most striking feature in this process is the gradual succession of changes, which precede its completion.

In the embryo two substances are met with occupying the place of bone; in the room of the upper and lateral parts of the cranium a membranous sac is found; in other parts there are cartilages modelled in the form of the future bones.

Between the sixth and eighth week, on either side of the forehead of the embryo, the membranous sac, which occupies the place of the future cranium, contains a deposit of bone; and *a thin network* of the finest bony fibres may be drawn from between the two layers, into which it is separated.

About the same time bone is formed in the clavicles, in the ribs, in the vertebræ, in the sphenoïd and occipital bones, in the jaw bones, in the scapulæ, and in the shafts of the long bones. In each of these instances, the type, in which bone is originally deposited, appears the same: but as bone grows, the structure which it seems to assume has reference to the form, which the bone is destined eventually to bear. Thus the flat bones in their subsequent growth appear composed of fibres radiating from a centre; the long bones, of successive rings produced by an elongation of parallel and longitudinal fibres.

At the time of birth, the bones of the cranium though thin nearly meet, a certain extent of membrane being interposed: the vertebræ are three bones joined by portions of cartilage: the separate parts of the tarsus and carpus, and the patella, are cartilages; and under the name of epiphyses the margins of the flat bones of the shoulder and pelvis, the heads of the ribs, and both extremities of the long bones, are portions of the same substance, the connexion of which to the bony part is extremely slight; but the central ossification continually encroaches upon the cartilaginous extremities; and in most of the epiphyses separate points of ossification commence, which proceed to meet the extension of the shaft.

In this slow succession of changes, we trace an accommodation of the frame to the different circumstances under which it is placed; the soft and tender flesh of an infant would be injured by pressure against solid bone. The bones of the head, if already joined suturally, would not yield at the time of labour. The frame is light and incapable of violent efforts; the organs which support it are pliant, elastic, and yielding.

It is not till past the age of twenty that the bones are perfected: *at* that age, the epiphyses though complete have not entirely coalesced with the shaft or central ossification of the bone; and a narrow furrow observable upon the surface of a macerated bone, shows where a thin layer of cartilage had still partially intervened.

No texture better developes the common law of growth than bone:—exercise it, and it enlarges: where a powerful muscle is attached, the surface of a bone projects in a ridge or tubercle: if it fall into disuse, bone shrinks, and loses its weight and volume.

When a tooth is broken across, or a hair divided, the part detached has no means of reunion with the rest. But when a bone is broken, when a sinew, a nerve, a muscle, is divided, the disjoined surfaces spontaneously re-unite.

When the skin is divided by a clean incision, the blood, which for a short time flows abundantly, after a minute or two scarcely oozes, and finally ceases. If what rests upon the surface be gently washed away, a narrow red line shows the edge of a thin clot of blood, by the adhesive quality of which the divided surfaces are held in apposition; but the adhesion at first is slight, and the wound may easily be drawn open. If the incision be superficial and of no great extent, in twenty-four hours complete union appears to have taken place: and when in a day or two afterwards the red edge of the clot peels off, cuticle is found below it; but the linear surface remains of a darker hue for several days.

When a small portion of the body is entirely separated, as for instance, the tip of the ear, the half of a finger, if it be immediately re-applied, mechanical adhesion takes place in a similar way, and the part lives.

When large cut surfaces are brought in contact, as after the removal of a breast, or the amputation of a limb, it appears that in general union is at first mechanically effected by the coagulated blood; but in most cases the inflammation, which follows, produces a tumefaction and a flow of various secretions, which prevent the first union holding more than partially. After a few days, the surface of the wound appears covered with a soft layer of vascular flesh, called granulations, from which pus is secreted; and which rising fill the cavity of the wound, and are converted into the nature of the substances, which they unite.

Pus is a viscid straw-coloured fluid, of the specific gravity of 1050, it coagulates when raised to the temperature of 112°, or when mixed with muriate of ammonia: its colour depends upon a number of globules, sensibly larger than the globules of the blood: it appears from the researches of Sir E. Home, that these globules are formed by chemical attraction in a fluid, which is limpid and colourless when first secreted.

When a considerable portion of skin is removed, the cellular membrane inflames below the blood which stiffens on the raw surface, and secretes pus, and forms a crop of granulations; these gradually rise to the level of and higher than the surrounding skin; the secreting surface appears to diminish daily, and becomes, in patches, or at its edges, converted into a tender whitish substance, which thickening becomes opake and forms a cicatrix; on the day that a portion of a cicatrix is completed, it is insensible; about a fortnight afterwards it feels, if pricked with a needle.

Thus in the formation of a cicatrix after destruction of the skin, the new material is produced not by the neighbouring cutis, but by a growth from the subcutaneous texture.

When tendons, or nerves, cartilages, or bones, are divided or broken across, the process of their re-union does not resemble the adhesion of divided skin, but has more in common with the growth of a cicatrix. The disjoined surfaces do not cohere immediately, but through the intervention of a third substance, which appears produced from the neighbouring cellular texture.

If the tendo Achillis be examined in a dog forty-eight hours after division, upon removing the skin, the subjacent cellular membrane, that surrounds the tendon, appears loaded with coagulable lymph, and extravasated blood. Upon making a longitudinal section of the thickened substance, the cut ends of the tendon contained within it are found to be about an inch apart, but connected together by means of coagulated blood, and swollen cellular texture.

If the tendo Achillis be examined seven days after division, the ends of the divided tendon are found united by an intervening substance of greater thickness than the tendon itself, that is readily separable from the skin.

and subjacent parts. Upon a longitudinal section being made, the intervening substance appears of a dark red colour, firm, and to a certain degree elastic: it coheres, in some parts firmly, in others slightly, with the cut ends of the tendon, but strongly and inseparably with the cellular sheath of the tendon, which is discoloured for some distance: so that either end of the tendon admits without much force of being displaced from a socket in the intervening substance.

At seventeen days after division, the intervening substance is found diminished in thickness, firmer, paler, and inseparably coherent with the cut ends of the tendon, the nature of which it gradually assumes.

When a nerve is divided, the process, by which its ends are joined, exactly resembles the mode in which tendons unite. Without detailing the appearances on dissection at an earlier period, let me describe the state of the part, at the time when the return of its function first manifests itself.

The infraorbital nerve was divided on one side upon the cheek of a cat, and a portion about a line in length was removed from it. The skin of the upper lip immediately lost sensation. The wound, however, readily cicatrized; and by the twentieth day sensation appeared entirely restored. Upon examining the part at this period, the nervous fibrils appeared to be united by a thick layer of tough gray semitransparent substance. On making a longitudinal section of this substance and of the nervous fibrils which entered it, the extremities of the divided filaments appeared nearly two lines asunder, and firmly coherent with the intervening substance: here and there a whitish fibril seemed to extend further into the connecting medium, but no restoration of continuity between the nervous fibrils was observable.

When the portio dura is divided on the cheek, it unites in a similar manner; but the nerve does not begin under four weeks to resume the office of transmitting the influence of the will. About this time, however, the eyelids, which hitherto have been motionless, are observed to be slowly and imperfectly drawn towards each other, whenever the surface of the conjunctiva is touched.

If the cartilage of a rib be examined in a dog forty-eight hours after division, the cut surfaces of the cartilage are not found to have undergone any change: they are held together by a loose capsule formed by the surrounding parts. Towards the seventh day, this capsule has assumed a dense elastic texture, and distinctly includes the adjacent cellular membrane and muscular substance. The edges of the cartilage appear rounded off, and a slight exsudation of lymph seems interposed between the disjoined surfaces. On the seventeenth day the appearance is much the same; the intervening substance, which has acquired consistence, is continuous with, and appears derived from the capsule. About the twenty-eighth day, the intervening layer of lymph is found adhering to and loosely uniting the opposite cartilaginous surfaces.

The changes, which attend the re-union of a broken bone are even more elaborate than those, which occur in the preceding instances. The most valuable observations, which have been published upon this subject, are by M. Dupuytren.

If a fractured limb be examined within forty-eight hours after the injury, the periosteum is found to have been stripped irregularly from the broken ends of the bone: the cancelli of the bone and the neighbouring soft parts seem in a state of ecchymosis; the quantity of blood, however, effused from the ruptured vessels is generally inconsiderable.

About the fourth day a change is found to have supervened; the parts adjacent to the broken ends of the bone have become condensed and indurated, and form a firm capsule which contains the broken extremities. The thickening includes every neighbouring texture: the muscles, tendons, and cellular membrane, for the extent of a few lines seem condensed into one tough elastic mass.

During the next fortnight this capsule becomes of greater firmness, assuming the character of cartilage: at the same time lymph is frequently found to have exsuded around the broken ends of the bone.

After the third week the muscles and tendons gradually become again distinct, or disengaged from the thickened capsule, in which ossification soon commences: so that at the expiration of four or five or six weeks, the broken ends of the bone are fixed in some sort of apposition by an osseous case extending from the one to the other, having its adhesion at some little distance beyond the fractured edge. The only union between the *extremities* of the bones, that hitherto has taken place, is by soft substance, which comprehends the organized clot of blood, the lymph effused, and productions from the capsule, which have grown together and coalesced.

During the interval between the sixth week and the fifth or sixth month, the process of ossification extends from the capsule, to the soft substance which directly unites the broken surfaces. At the same time the capsule shrinks in proportion as the direct union renders it unnecessary. After a few months more, the capsule has disappeared, the bone has shrunk to the natural size, and even its cavity is gradually restored.

Thus it appears established upon a very extensive induction, that union of internal parts greatly depends upon changes, which take place in the adjacent textures. This conclusion derives support from, at the same time that it serves to explain, the curious circumstance, that fractures of an isolated bone never unite by bone. In Sir Astley Cooper's capital work upon Dislocations the fact is proved by reference to a vast body of evidence, that when the neck of the femur is broken within the capsular membrane, bony union does not follow.

Of several instances, which I have myself had an opportunity of examining, let me select the following to illustrate this anomaly. A woman about the age of fifty fell with great violence upon the left hip. The limb was not shortened, but was rendered useless: pain and swelling followed. She was confined to her bed for five months; after which she gradually regained strength in the injured hip, and became enabled to walk with the assistance of a stick. Thirteen months after the accident, she died suddenly of apoplexy. Upon examination, the neck of the femur was found to have been broken within the capsular membrane: union had taken place by a layer of soft but tough substance three lines in thickness, in which however not the least trace of earthy matter was discovered. The specimen is in the Museum in Great Windmill Street, and was given to me by my friend Mr. Sweatman: there is an engraving from it in Sir Astley Cooper's work on Dislocations. In a fracture of this description it is obvious that the broken ends of bone remain inclosed in a synovial cyst, excluded from the contact of those parts, the changes in which accomplish union in other cases.

When the neck of the femur is broken, and the fracture is half within and half without the capsular membrane, the former part unites by ligament, the latter by bone.

When the fracture is entirely within the capsular membrane, and ligamentous union ensues, some growth of bone is occasionally found to have occurred on the outside of the capsular membrane,—the commencement of the same process, which has been already described in the ordinary reparation of bone, but which in this case is prevented extending to the substance that intervenes between the broken surfaces.

Let me conclude with mentioning an instance of deficient union after partial division of a nerve, which seems to be singularly parallel to the case last considered.

An attempt was made to divide the fifth nerve at the side of the pons Varolii in a young cat. The animal immediately lost the sense of feeling in the parts supplied by the first and second divisions of the fifth, and the cornea became partially opake: but the iris moved, and the animal saw distinctly with the eye, which had lost the sense of touch. During eighteen months no further change ensued: not the slightest return of common sensation was observable in the eye, the nostril, or cheek of the mutilated side. At this period the animal was killed. Upon examination, the following appearances presented themselves. The fifth nerve had not been entirely divided; which accounted for the continuance of sensation that had been observed in the parts supplied by the third division of that nerve. What remained undivided of the fibrils of the fifth held the severed portions at the distance of a line asunder: they were united by a thin film, which seemed a thin clot of blood, which had nearly lost its colouring matter, and gave way on slight pressure.

Now a nerve when traversing the cavity of the arachnoïd membrane is in a position analogous to that of the neck of the thigh bone: it is not in any sort of contact with the cellular texture; and its restoration when divided is equally imperfect.

Yet in such a case every other condition favourable to reparation is present: the divided surfaces are nearly in apposition, the supply of blood is not interrupted, and the parts are kept perfectly at rest.

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APPENDIX.

IN page 95 I have mentioned the discrepancy which exists between the observations of Mr. Brodie and of M. Magendie respecting the influence of the bile in digestion. The following experiments, which I have subsequently made, agree in their result with Mr. Brodie's.

"The ductus communis choledochus was tied in three cats, each about four months old, which had fasted for twenty-four hours previously. They each took food after the operation, which they threw up; but they afterwards again took food, consisting of milk and raw or boiled meat, and continued to eat occasionally with a natural appetite.

"One of these animals was killed between five and six hours after the duct had been tied. The stomach contained a full meal of meat, consisting in part of morsels, which were softened by the action of the gastric juice, but had undergone no further alteration; in part of a pulpy mass of a reddish grey colour, in part of a brownish-grey viscid liquid, in which innumerable small globules of oil floated. The small intestines were perfectly empty.

"The second died within fifty hours after the experiment. The stomach contained a small quantity of half-digested food; the small intestines contained scarcely a trace of a greyish semifluid substance, which here and there admitted of being scraped from the villous surface.

"The third was killed three days after the operation. The stomach contained half-digested food; the small intestines contained a quantity of a greyish viscid liquid, very like the liquid contents of the stomach. The great intestines, in this and the preceding instance, were distended with a greyish, tenacious, and highly offensive semifluid matter.

"An adult dog, in which the duct had been tied, was found dead on the second morning of the experiment. The mucous membrane of the stomach and bowels was inflamed; the stomach contained water only; the small intestines held a quantity of yellowish ropy liquid.

"Finally, the duct was tied in two young dogs, which had fasted for twenty-four hours; one died, the second was killed, about forty-eight hours after the operation. Both had eaten boiled flesh, and had taken milk. In the first the stomach contained half-digested food; and the small intestines contained a quantity of grey liquid, separate from a viscid ropy material that adhered to the villous surface. In the second the stomach contained a frothy mucus only; but the small intestine was moderately distended with a quantity of yellowish liquid.

"The animals which were killed were immediately examined: those which died were examined from four to five hours afterwards. In each case the duct was found to have been accurately secured; the gall-bladder and gall-ducts were distended with bile: *there was no trace whatever of chyle in the lacteal vessels*[a]."

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[a] Medical and Physical Journal for October 1826.

THE END.

Printed by Richard Taylor,
Shoe-Lane, London.

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